Gulf Research Reports

Volume 2, Number 2

Ocean Springs, Mississippi

OCTOBER 1966

Gulf Research Reports

Volume 2 | Issue 2

January 1966

Oyster Abundance in Apalachicola Bay, Florida in Relation to Biotic Associations Influenced by Salinity and Other Factors

R.W. Menzel
Florida State University

N.C. Hulings
Florida State University

R.R. Hathaway
Florida State University

DOI: 10.18785/grr.0202.01

OYSTER ABUNDANCE IN APALACHICOLA BAY, FLORIDA IN RELATION TO BIOTIC ASSOCIATIONS INFLUENCED BY SALINITY AND OTHER FACTORS[1]

by

R. W. Menzel, N. C. Hulings and R. R. Hathaway

Oceanographic Institute, Florida State University
Tallahassee, Florida

Abstract

From June 1955 through May 1957, stations on three oyster reefs were sampled quantitatively at intervals and all oysters and associated macroscopic organisms were recorded per unit area. Station I was a privately leased "natural" reef, consisting of higher places exposed at low water, with a salinity range of 22.7-36.6 o/oo and was fairly productive. Station II, depth ca. two meters, was the least saline, range 1.2-29.3 o/oo, and was considered very productive for natural reef. Station III, depth one meter, salinity range 7.5-35.7 o/oo, was depleted although there was an abundant spatfall.

Depth and bottom types as well as salinity were found to delimit certain species of animals. Analysis of past records showed that the bay had formerly been less saline; there was an extended drought in the watershed before and during the investigation. As a result several species of animals less euryhaline than oysters became established on some of the reefs. At Station III, two serious oyster enemies, Thais haemastoma *Say and* Menippe mercenaria *Conrad were abundant. A field experiment at this station during the second year pointed to these two enemies as the main cause of the depletion of the reef. Near the end of the investigation rainfall became more nearly normal and the lowest salinities were recorded at this time. The reduction in salinity, especially at Station III, eliminated many of the less euryhaline species, including drills and stone crabs, and the reef later regained its former productivity.*

[1] Contribution No. 213, Oceanographic Institute, Florida State University. This study was supported by a contract with the U. S. Fish and Wildlife Service through Saltonstall-Kennedy Funds.

Introduction

Apalachicola Bay, Franklin County, is the center of oyster production in Florida, producing about 85% of the state's crop. Quantitative samples were made of the oysters and associated biota to determine if such sampling would delineate a non-productive oyster reef from a productive one. The presence or absence of certain organisms, especially known oyster enemies, as well as their abundance, was correlated with salinity and other physical factors. Stations were established on non-productive and productive oyster reefs of high and low salinities and shallow and deep water. The study extended from June 1955 through May 1957.

There have been several studies of the oyster reefs in the region of East Bay, Indian Lagoon, St. Vincent Sound, Apalachicola Bay, St. George Sound, which are known collectively as Apalachicola Bay. Ingersoll (1881) mentioned the oyster fishery of the area and later Swift (1897) made an extensive survey of the region. Moore (1897) discussed the organisms collected by Swift. Danglade (1917) studied all the oyster reefs of the region and attempted to determine the density of oysters on several of the producing reefs. Pearse and Wharton (1938), in their study of the oyster "leech", gave considerable information on the biota and hydrography of the region. Ingle and Dawson (1953) made a recent survey of the oyster reefs and have published on the spawning, setting, growth and conditions of the oysters (Ingle, 1951a; Ingle and Dawson, 1950, 1952).

DESCRIPTIONS OF STATIONS AND METHODS

Three stations (described below) were selected for study because they represented different ecological conditions (Figure 1).

STATIONS IN APALACHICOLA BAY

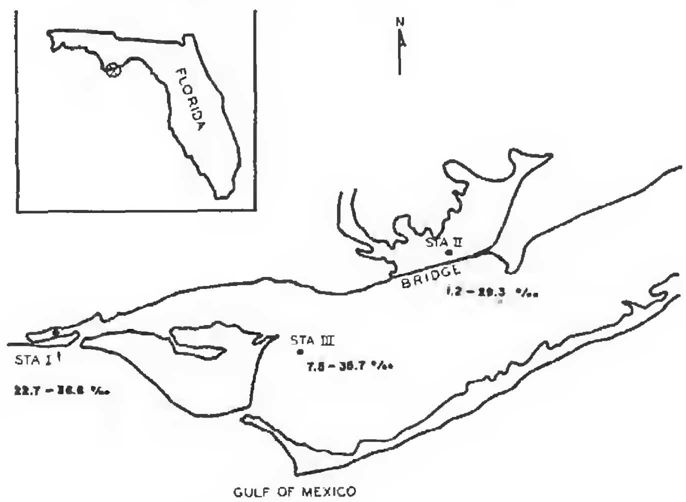


Figure 1. Map of Apalachicola Bay showing locations and bottom salinity ranges of stations.

Station I

Station I was a reef located in the middle of Indian Lagoon on privately leased ground that is harvested sporadically. At mean low water the top of the reef is exposed. The top of the reef is approximately one-half meter higher than the lower edges. The surrounding area has a mud bottom and an average depth of less than one meter at mean low water. The reef is relatively small, about 175 meters long and 20 meters wide in the middle, and tapers gradually at both ends. Bottom salinities during this study ranged from 22.7 o/oo to 36.6 o/oo (Table 1).

Although many single oysters were present, the majority occurred in clusters up to about ten. The oysters were more numerous on the lower edges of the reef than on the higher middle part, which had more shells and smaller oysters and a firmer substrate than the lower edges. Though not large, oysters were thick-shelled, deep-cupped, and rounded.

Station II

Station II was located in polluted water north of Gorrie Bridge where the depth was from 2 to 3 meters. The main reef of oysters is rather narrow and extends about 500 meters northward from the bridge. The bottom is firm on the reef (it was estimated that the shells and oysters were a foot or more thick), but is fairly soft in other areas.

The maximum size of the oysters was greater than at Station I. This reef was opened for commercial exploitation each winter during the investigation, when the pollution cleared. The bottom salinity ranged from 1.2 o/oo to 29.3 o/oo (Table 1).

Station III

Station III was established on St. Vincent Bar. The reef is extensive, and although several small sectors are exposed at low water, most of it is under a meter or more of water. Masses of shell fragments (mainly oyster) cover the reef. The bar is in an exposed position in the bay and is subject to the vagaries of estuarine conditions. The currents are swifter here than at any of the other stations. The general location of the sampling was in a depth of one meter at low tide. The bar is reported to have been productive in former years, and the dense masses of shells support this. During the investigation, however, it produced no market oysters, although spatfall was heavy. The bottom salinity ranged from 7.5 o/oo to 35.7 o/oo (Table 1).

Field Procedures

During the first year of observation (June 1955-May 1956) sampling trips were made to all stations at approximately monthly intervals. During the second year, Station III was sampled at monthly intervals, but Stations I and II only seasonally.

Each station was sampled quantitatively by collecting all the oysters and the associated macroscopic organisms in a measured area. Frames were made with areas of one square meter and one-fourth square meter. In sampling Station I, two transects, ten meters apart, each one meter wide and 20 meters long, were established parallel to the short axis of the reef. Samples were taken from one transect and near (but outside) the

TABLE I

Monthly bottom salinity reading (o/oo) and surface temperature (°C) at the three stations in Apalachicola Bay

	I		II		III	
Date	o/oo	°C	o/oo	°C	o/oo	°C
1955						
June	36.3	28.5	—	27.5	—	—
July	31.0	33.0	—	29.5	—	—
Aug	29.1	32.0	—	32.1	—	—
Sept	22.9	27.5	—	27.3	28.5	29.5
Oct	29.5	23.0	—	22.9	29.0	23.0
Nov	31.2	23.0	28.6	19.0	18.8	21.0
Dec	29.1	8.1	27.2	10.2	17.3	12.1
1956						
Jan	30.4	13.6	6.6	11.0	22.7	13.7
Feb	23.5	15.0	1.2	14.0	13.7	16.0
Mar	32.9	13.0	7.1	14.1	32.1	14.4
Apr	35.3	19.2	—	—	10.3	19.5
May	36.6	27.1	26.8	23.3	16.2	26.0
June	—	—	29.3	28.0	35.7	29.0
July	—	—	26.5	29.0	34.4	29.0
Aug	32.3	32.9	—	—	27.5	30.0
Sept	—	—	—	—	22.6	28.0
Oct	—	—	—	—	19.7	24.4
Nov	30.7	20.5	—	—	24.3	19.0
1957						
Jan	27.8	16.4	—	—	35.7	14.9
Feb.	—	—	—	—	—	—
Mar	—	—	19.7	17.0	30.6	16.5
Apr	—	—	—	—	10.6	20.0
May	27.0	24.0	—	—	7.5	24.0

other. The second transect was left and treated as a control area. Two one-fourth square meter samples were taken from each edge and two from the middle of the reef. The reef was usually sampled at the low tide when it was either exposed or in very shallow water.

At Station II an attempt was first made to anchor a one-meter square frame to the bottom and to tong all oysters and other organisms within the frame. This was abandoned and SCUBA was used thereafter. After the reef was located, the frame was cast at random from a motor launch. The diver then collected all material by hand from the enclosed area of the frame. Three one-square-meter samples were taken the first year and four one-fourth-square-meter samples were taken the second year at each sampling. At Station III, because of the shallow water SCUBA was not used, but hand collections were made with the aid of a face mask.

Surface water temperatures and bottom salinity samples, were taken and a U.S.C.G. and G.S. hydrometer (Emil Griener and Co.) was used to determine salinity (Table I). On September 7, 1956, surface and bottom samples were taken at 30 minute intervals at Station III, over a 12 hour period.

A field experiment was conducted at Station III during the second period of observation in which an attempt was made to protect oysters from predators. Baskets were constructed of one-half inch mesh hardware cloth and filled with twelve liters of the shelly bottom material, from which all large predators were removed. Twenty-four such baskets were utilized. Two of the baskets were removed for examination concurrently with four one-fourth-square meter bottom samples, during each trip to the station.

One hundred large oysters from Station I and 100 from Station II were transplanted to Station III for mortality studies. These oysters (25 per basket) were placed in baskets similar to those containing the shelly bottom material. These experiments yielded some information but were not completed because the baskets were lost after several months.

Laboratory Procedures

All the samples were analyzed in the laboratory at Florida State University. The oysters were measured to the nearest half-millimeter in length and numbers tabulated in size intervals; Interval "1" - oysters below 10 mm long (not recorded except for Station III); Interval "2" - oysters between 10.0 and 19.5 mm long; . . . ; Interval "14" - oysters between 130.0 and 139.5 mm long. Recent mortality in the various size intervals was estimated by the fouling on the shells. The determination of the species composition of oysters from Station III was made by opening and examining the shells of approximately 100 oysters. The species *Ostrea equestris* Say was abundant at this station along with the commercial oyster *Crassostrea virginica* (Gmelin). A twelve liter sample of culled oysters from Stations I (edges of reef) and II was counted, weighed to the nearest gram in the shell and shucked; the volume of the drained meat was measured to the nearest milliliter.

All of the conspicuous faunal elements were identified and particular attention was given to enemies and possible enemies of oysters. Abundance of each species was estimated during the first year as follows: abundant ("A") - more than 10 per square meter; common ("C") - 4 to 10 per

square meter; rare ("R") - 1 to 3 per square meter; present ("P") - no estimate of numbers could be made (e.g., blue crabs, encrusting bryzoans). The number per unit area was determined for some species, mostly during the second year of study. The data have been tabulated as numbers per square meter. Oysters from the several stations were examined for *Dermosystidium marinum* Mackin, Owen and Collier by use of the thioglycolate method.

Although samples were usually taken at monthly intervals, numbers of oysters are given on a seasonal or quarterly basis. The quarters are January-March, April-June, July-September and October-December. Thus the seasonal data will include an average of as many as nine one-square-meter samples for Station II during the first year of observations and as few as four one-fourth-square-meter samples for this station during the second year.

RESULTS AND DISCUSSION

Salinity

The ranges of salinities for the stations are shown in Figure 1 and Table 1. Since these were monthly samples, they can give only a general idea of the hydrographic conditions. The salinity samples taken during the present investigation show wide fluctuations but salinity was generally highest at Station I, slightly less at Station III, and lowest at Station II. This sequence would be expected from the location of the several stations. Previous investigations in the bay have shown rapid and wide fluctuations in salinities, influenced by freshets, tides, currents, and wind direction and velocity (Dawson, 1955a; Ingle and Dawson, 1950, 1953).

The twelve-hour survey at Station III showed that the salinity varied nearly 4 o/oo at the surface and nearly 5 o/oo at the bottom during the period. Concurrent samples taken at the surface and bottom never differed more than 3.4 o/oo; the majority showed top-to-bottom difference of less than 0.5 o/oo. There was little tidal exchange at this date because of a strong easterly wind. Possibly under other conditions, when there would be more in-and-out water movement, the hourly fluctuations as well as the stratification in salinity would be greater. Station III is a shallow water station and stratification was found to be greater in deeper water. Station II, which had the deepest water of all stations (and was also closest to the influence of river runoff), sometimes had top-to-bottom differences of as much as 20 o/oo.

Salinities recorded by previous investigations (Pearse and Wharton, 1938; Ingle and Dawson, 1950; Dawson, 1955a) and those of the present investigation are summarized in Table 2. These data indicate that overall salinity was higher than during the earlier investigations. There had been an extended drought in the watershed of Apalachicola Bay, but beginning

in the spring of 1957, precipitation had become more normal, and the lowest salinities during the present study were recorded at this time. The salinity of the area should become more stable due to the construction of the Woodruff Dam on Apalachicola River and the opening of passes to the Gulf through the barrier islands, both of which were completed since the termination of this investigation.

TABLE 2

Comparison of salinities (o/oo) taken in Apalachicola Bay region in 1935-36, 1949-50, 1953-54, and 1955-57.

Investigator and Date	Depth	Station I Low	Station I High	Station III Low	Station III High	Station II Low	Station II High
Pearse and Wharton 1935-36	Surface	5.97	32.45	0.00	20.19	0.40	32.46
	Bottom	5.97	34.41	0.10	28.66	0.60	34.58
Ingle and Dawson 1949-50	Surface	16.1	43.8	—	—	2.6	39.4
Dawson 1953-54	Surface	18.4	37.2	1.2	18.4	4.1	35.1
Present authors 1955-57	Surface	—	—	0.0	25.8	7.5	35.1
	Bottom	22.7	36.6	1.2	29.3	7.5	35.7

Spatfall

In the following discussion the presence of a large number of oysters in the smaller size intervals is assumed to indicate recent spatfall. *Ostrea equestris,* as well as *Crassostrea virginica,* occurred at Stations I and III (sometimes in equal numbers at Station III) but the discussion and the figures are only of *Crassostrea.*

The heaviest spatfalls at Station I on the edges of the reef occurred during the fall of 1955 and the summer of 1956 (Figure 2). On the middle of the reef the greatest numbers of small oysters were found during the fall in both years (Figure 3).

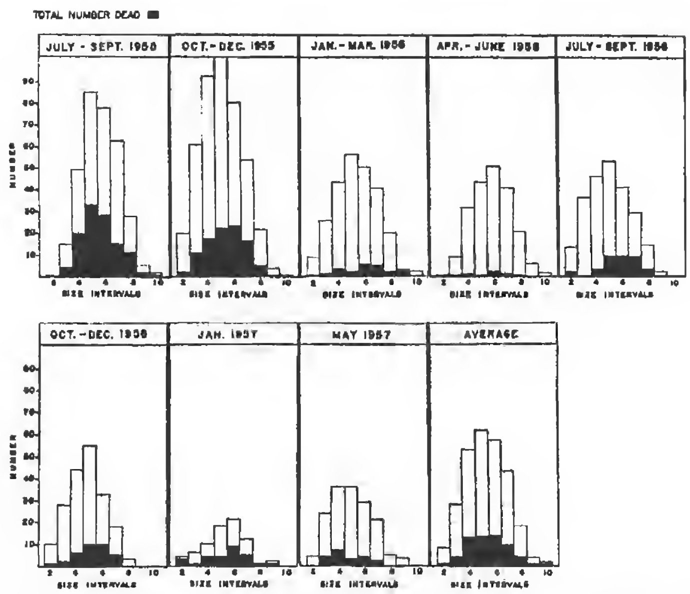


Figure 2. Seasonal average total number of *Crassostrea* and number dead per square meter in each size group during sampling period, STATION I, edge.

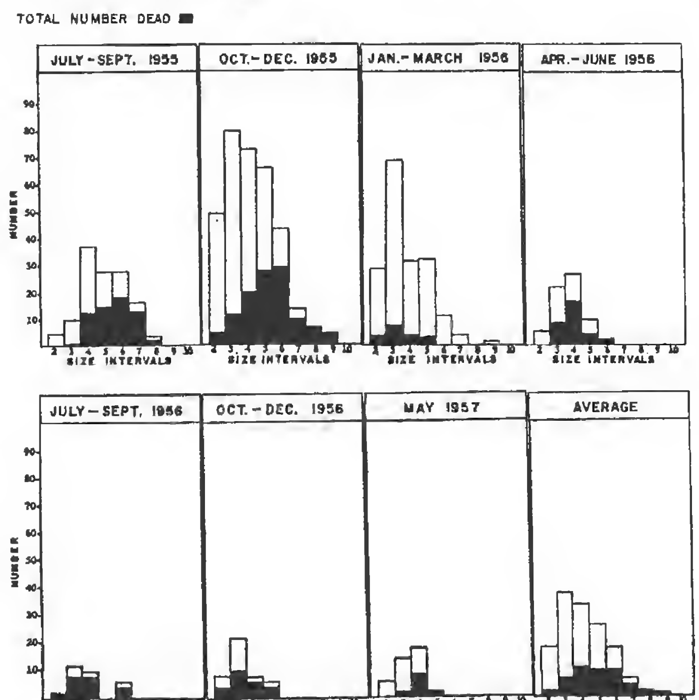


Figure 3. Seasonal average total number of *Crassostrea* and number dead per square meter in each size group during sampling period, STATION I, middle.

Station II never had a heavy spatfall (Figure 4). It is surprising that the oysters in this area maintained such a level of abundance since there was a constant loss from mortality and harvesting. The area has fewer natural enemies than other stations examined and the lack of enemics probably accounts for the sustained production despite the low spatfall. Ingle and Dawson (1953) also found that, generally, the spatfall was lighter on the less saline reefs.

Station III had a heavy spatfall during both years of the investigation. Figure 5 indicates that spatfall on the bottom was greatest in the summer and fall. Spatfall in the baskets (Figure 6) was heavy at all times, but especially in the spring. Monthly data (not shown) indicate heaviest spatfall in late May and June.

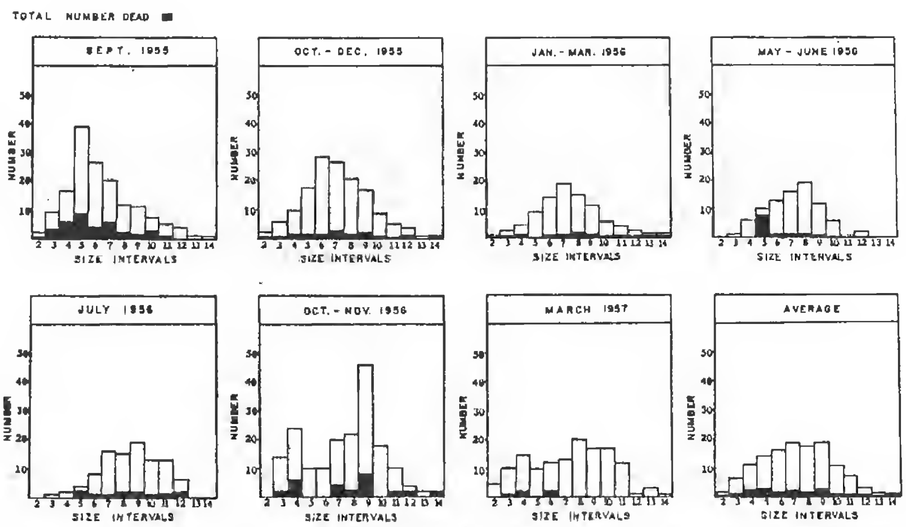


Figure 4. Seasonal average total number of *Crassostrea* and number dead per square meter in each size group during sampling period, STATION II.

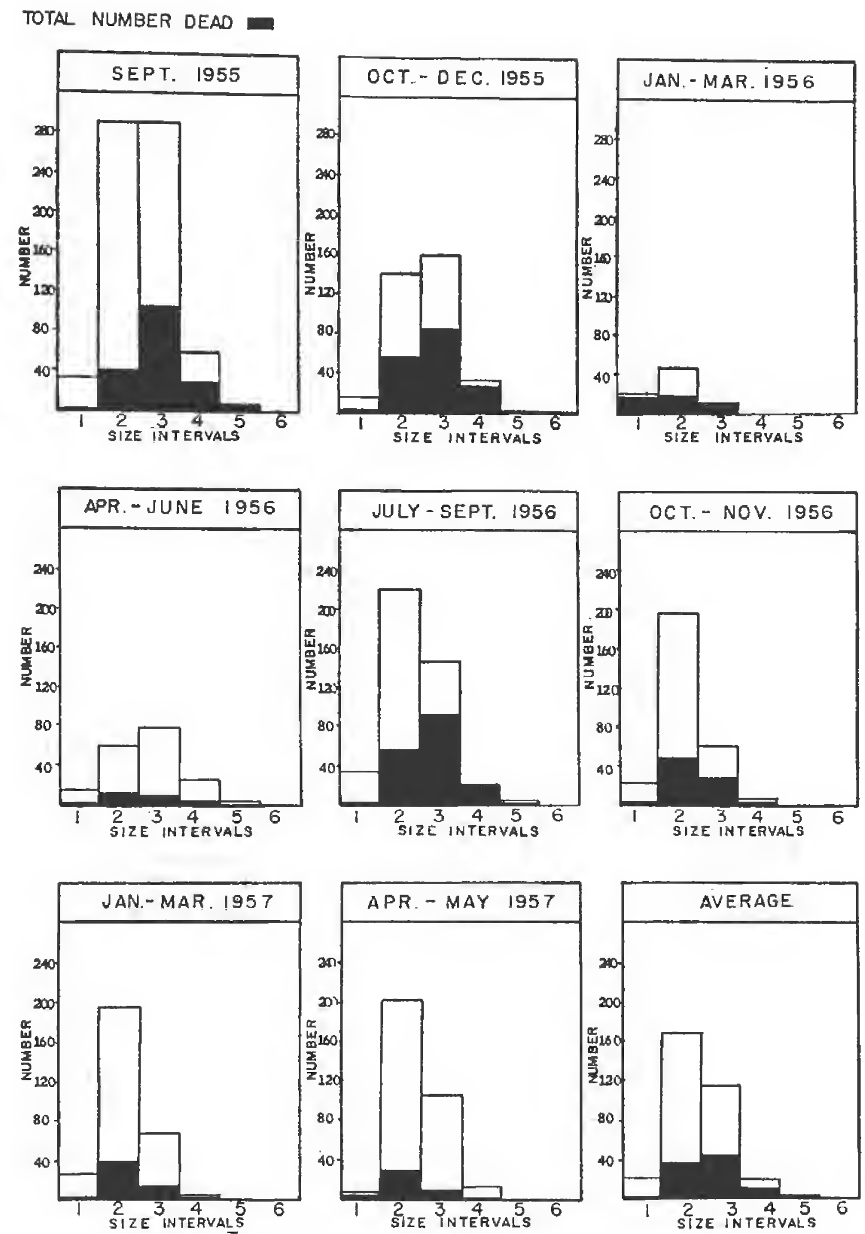


Figure 5. Seasonal average total number of *Crassostrea* and number dead per square meter in each size group during sampling period, STATION III.

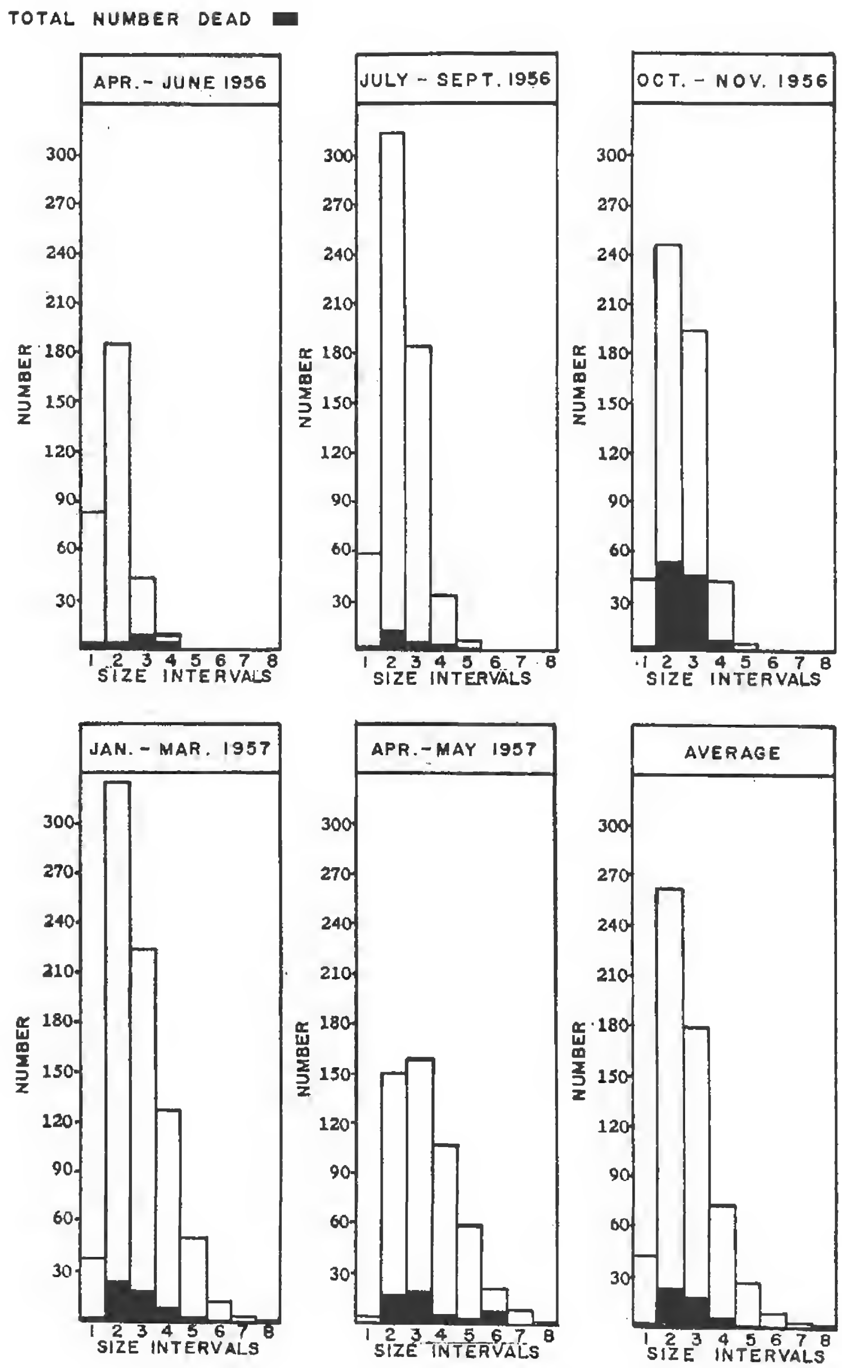


Figure 6. Seasonal average total number of *Crassostrea* and number dead per basket in each size group during sampling period, STATION III.

Mortality

The mortality data, based on a judgment of recent deaths, are very conservative estimates. The difference in growth rates of fouling organisms at various times of the year, the time of separation of the valves of various size oysters and other factors, all make it difficult to determine recent mortality. Gunter, Dawson and Demoran (1956) have discussed problems which apply here in determining oyster mortality.

At Station I the mortality was greater on the middle of the reef than on the edges and was less the first year than the second (Figures 2, 3). Station II had much less mortality than Station I (Figure 4). Mortality was very high at Station III during all periods of the year. The oysters in the baskets had less mortality that those on the bottom (Figures 5, 6).

Mortality was heaviest in summer and fall, especially on the edges of the reef at Station I. The high summer and fall mortality is correlated with the greater activity of predators and incidence of disease during these seasons. A more detailed discussion of the mortality at Station III is given by Menzel, Hulings and Hathaway (1957). On the average the greater proportion of dead oysters at all the stations was found in the larger size groups, but these data are due partly to the method used in determining mortality.

Growth and Size

Oyster growth is very rapid in the Apalachicola Bay area (Ingle and Dawson, 1952). Shell size increases throughout the year. Our data show some evidence of growth in the change in modal length between sampling periods. At some stations, however, the mode remained the same throughout the period because of the mortality and recruitment.

At Station I, few oysters reached 100 mm in length (Figures 2 and 3). The average modal length at the edge of the reef was 40.0-49.5 mm. In the middle of the reef, the modal length was 20.0-29.5 mm.

Samples of oysters collected at Station II showed a progressive increase in length (Figure 4). In September 1955 the mode was at 40.0-49.5 mm, and throughout the year this value increased until July 1956, when a maximum modal length of 80.0-89.5 mm was reached. In the following sampling period (October-November, 1956) a clear bimodal distribution in length was found. It appears, from the length distribution found at the two periods, that a spatfall occurred during the summer. At Station II, number of oyster per square meter, especially larger oysters, decreased during the spring, perhaps because of commercial harvesting as well as mortality.

At Station III, measurements were made of samples from the bottom and from basket culture. No oysters reached a length greater than 50 mm on the bottom and the majority were between 10 and 30 mm long (Fig-

ure 5). In samples from the baskets (Figure 6), growth was reflected in increasing numbers of larger oysters during the year, although the modal length remained constant.

Market Oysters

Oyster farming in Apalachicola Bay has not developed commensurately with the potential that exists, despite the abundance of seed oysters and the fast growth. Most of the market oysters are produced from more or less wild stock, despite extensive shell plantings for cultch in certain areas and experimental plantings by the State Board of Conservation to demonstrate the feasibility of oyster culture.

TABLE 3

Weights (gm) in shell and volume (ml) of shucked meat of oysters from a 12-liter sample at Stations I and II

	Total No. Oysters		Total Weight		Meat Volume	
Date	I	II	I	II	I	II
1955						
Aug.	120	—	8,530	—	490	—
Sept.	167	100	9,451	8,750	550	420
Oct.	192	142	10,115	7,600	600	675
Nov.	150	77	10,185	7,450	725	510
Dec.	114	—	10,450	—	750	—
1956						
Jan.	111	87	10,200	8,400	750	725
Feb.	113	95	9,560	7,600	750	850
Mar.	108	99	8,800	8,180	650	650
Apr.	131	—	8,590	—	890	—
May	110	126	8,100	8,300	725	550
June	—	116	—	9,550	—	620
July	—	93	—	9,250	—	525
Aug.	108	—	8,175	—	525	—
Nov.	110	88	6,750	8,250	520	675
1957						
Jan.	101	—	9,435	—	950	—
Mar.	—	93	—	9,050	—	690
May	116	—	9,795	—	985	—

TABLE 4

Organisms found at the three stations in Apalachicola Bay, Florida

Organisms	Stations I	II	III
Fungus			
Dermocystidium marinum Mackin, Owen and Collier	X	X	X
Porifera			
Cliona vastifica Hancock	X	O	X
Coelenterata			
Astrangia sp.	O	O	X
Bryozoa			
Membranipora sp.	X	X	X
Platyhelminthes			
Bucephalus cuculus McCrady	X	X	O
Stylochus frontalis Verrill	X	X	X
Annelida			
Neanthus succinea (Frey and Leukart)	X	X	X
Sabella sp.	X	X	O
Polydora websteri Hartman	X	X	X
Arthropoda			
Balanus eburneus Gould	X	X	X
Callinectes sapidus Rathbun	X	X	X
Clibanarius vittatus (Bosc)	O	O	X
Menippe mercenaria Say	X	X	X
Neopanope packardi (Kingsley)	O	O	X
N. texana Stimpson	X	X	X
Panopeus sp.	O	O	X
Petrolisthes armatus (Gibbes)	X	X	X
Synalpheus minus (Say)	X	O	X
Mollusca - Gastropoda			
Anachis obesa (Adams)	O	X	X
Cerithiopsis greeni (Adams)	O	O	X

Crepidula plana Say	X	X	X
Epitonium sp.	O	O	X
Kurtziella sp.	O	O	X
Melongena corona Gmelin	X	O	O
Mitrella lunata (Say)	O	X	X
Odostomia impressa Say	X	X	X
Polinices duplicatus (Say)	O	O	X
Seila adamsi H. C. Lea	O	O	X
Thais haemastoma Conrad	X	O	X
Triphora nigrocincta (Adams)	O	O	X
Mollusca - Pelecypoda			
Abra aequalis Say	O	X	O
Anadara transversa Say	X	X	X
Anomia simplex Orbigny	X	X	X
Brachidontes exustus (L.)	X	O	X
B. recurvus (Rafinesque)	X	X	X
Chione cancellata L.	O	O	X
Crassostrea virginica (Gmelin)	X	X	X
Corbula sp.	O	O	X
Martesia smithi (Tryon)	X	X	X
Mulinia lateralis (Say)	O	X	O
Noetia ponderosa Say	O	O	X
Ostrea equestris Say	X	O	X
Semele bellastriata Conrad	O	O	X
Trachycardium muricatum L.	O	O	X
Fishes			
Hypleurochilus germinatus (Wood)	O	O	X
Hypsoblennius hentz (LeSueur)	O	O	X
H. ianthus (J. and G.)	O	O	X
Opsanus beta (G. and B.)	O	O	X

X — Present

O — Not found

Although the oysters from Station I were of a smaller shell size than those at Station II (Figures 2, 3, 4) they often yielded more meat per unit measure (Table 3). This was especially true during the summer months. Visual inspection at time of shucking showed that the meats from Station I were generally in better condition than those from Station II. The drop in meat yield during the summer and the rise in the period from December through March, is typical of other oysters in the Gulf (Gunter, 1942; Hopkins, Mackin and Menzel, 1953).

A rough estimate can be made of the production of live market oysters for Stations I and II. Figures are calculated from the data of average numbers of live oysters over 70 mm long per square meter and the numbers of oysters of this size needed to fill a 12 liter container. These data may be converted to bushels per acre. For Station I, only the west and east edges of the reef are used, and at this station the estimate was about 225 bushels of live market oysters per acre during the period of the investigation. At Station II, the yield was estimated to be an average of 715 bushels per acre during the period. At times, especially in November 1955 and 1956, before the reef was opened for commercial exploitation, the yield would have been twice as high.

The yield from Station I, though not exceptional, was fairly good, especially when the ease of harvesting from a very shallow reef is taken into consideration. The yield from Station II is considered exceptional for a natural oyster bed, since this reef was subject to intensive harvesting each year. When the reef was open, the oystermen concentrated their efforts in this area. Despite the restricted season (because of pollution) the harvesting of oysters from this area was probably as complete as from other areas that were open for tonging throughout the season. After several weeks many tongers left the area of Station II and returned to areas that had formerly been less productive, but were now comparatively more so.

Association of Organisms on Oyster Reefs

Apalachicola Bay is usually very turbid and probably for this reason macroscopic algae are not conspicuous. Species of green algae were seen on several occasions during the winter months at Station III when the water was less turbid, but no records were kept. Only animals are discussed here, except for the pathogenic fungus *Dermocystidium marinum.*

The organisms found and the stations where they occurred are in Table 4. Table 5 gives quantitative data on selected animals. The discussion that follows is mainly of the oyster enemies.

The pathogenic fungus *Dermocystidium marinum* occurs in Apalachicola Bay (Dawson 1955b) and was found at all the stations during the present investigation. The mortality of the larger oysters at the stations during the summer months suggested *Dermocystidium marinum* disease (Mackin 1951a, 1952; Ray, 1954). In the survivors of one of the growth baskets at Station III, infection ranged from none to heavy (Menzel, Hulings and Hathaway, 1957).

The boring sponge *Cliona vastifera* was present at all stations in the shells of older oysters and in dead shells. This was the only species of *Cliona* found in the bay.

TABLE 5

Occurrence of several animals at the three stations in Apalachicola Bay estimated during period, August 1955-May 1956; numbers given per square meter during period, June 1956-May 1957.

Date	*Neopanope texana*			*Petrolisthes armatus*			*Anachis obesa*			*Brachidontes exustus*			*Brachidontes recurvus*			*Crepidula plana*			*Odostomia impressa*		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Aug. 1955	A	C	—	R	R	—	O	C	—	A	O	—	R	A	—	A	A	—	C	C	A
Sept. 1955	A	C	A	C	R	A	O	C	C	A	O	A	R	A	R	A	A	A	C	C	A
Oct 1955	A	C	A	R	R	A	O	C	C	A	O	A	R	A	R	A	A	A	C	C	A
Nov. 1955	A	C	A	R	R	A	O	C	C	A	O	A	R	A	R	A	A	A	C	C	A
Dec. 1955	A	C	A	R	R	A	O	C	C	A	O	A	R	A	R	A	A	A	C	A	A
Jan. 1956	A	C	A	R	R	A	O	C	C	A	O	A	R	A	R	A	A	A	C	A	A
Feb. 1956	A	C	A	C	R	A	O	C	C	A	O	A	R	A	R	A	A	A	C	A	A
Mar. 1956	A	C	A	C	R	A	O	C	C	A	O	A	R	A	R	A	A	A	C	A	A
Apr. 1956	A	C	A	R	R	A	O	C	C	A	O	A	R	A	R	A	A	A	C	A	A
May 1956	A	C	A	R	R	A	O	C	C	A	O	A	R	A	R	A	A	A	C	A	A
Average	A	C	A	R+	R	A	O	C	C	A	O	A	R	A	R	A	A	A	C	A-	A
June 1956	—	7	62	—	1	12	—	6	5	—	0	—	—	42	1	—	35	A	—	73	84
July 1956	—	3	80	—	0	43	—	0	1	—	0	A	—	136	3	—	41	A	—	44	33
Aug. 1956	35	—	20	12	—	40	0	—	11	23	—	A	3	—	0	A	—	A	8	—	75
Sept. 1956	—	—	100	—	—	52	—	—	16	—	—	168	—	—	4	—	—	40	—	—	83
Oct 1956	—	—	59	—	—	5	—	—	16	—	—	26	—	—	0	—	—	11	—	—	96
Nov. 1956	13	1	106	5	1	4	0	2	60	—	0	16	—	16	6	20	16	6	6	111	21
Jan. 1957	18	—	80	11	—	4	0	—	56	32	—	130	3	—	0	48	—	40	68	—	98
Feb. 1957	—	—	64	—	—	2	—	—	48	16	—	48	—	—	0	—	—	52	—	—	86
Mar. 1957	—	9	15	—	0	4	—	3	28	—	0	A	—	12	7	—	12	78	—	36	62
Apr. 1957	—	—	90	—	—	1	—	—	13	—	—	208	—	—	0	—	—	34	—	—	52
May 1957	29	—	42	0	—	0	0	—	8	35	—	42	1	—	0	55	—	10	10	—	25
Average	23.8	5.0	65.3	7.0	0.5	15.2	0.0	2.8	23.8	26.5	0.0	91.1	1.8	51.5	1.9	41.0	26.0	33.9	23.0	66.0	65.0

The flatworm *Stylochus frontalis,* sometimes called the oyster wafer or leech (=*S. inimicus, vide* Hyman, 1940), was the subject of an extensive study by Pearse and Wharton (1938). They found that damage to oysters may be considerable when the worms occur in large concentrations, but concluded that they never cause extermination of the population in a particular locality. The worm was found in concentrations up to 50 per square meter at Station III on several occasions. The worms were also found at other stations and hence salinity was not a limiting factor in their distribution in the areas under study. The oyster mortality rate did not reflect their presence or absence.

The cercariae of *Bucephalus cuculus* were found at all stations (Table 4). The highest percentage of infection was at Station I. In one sample 20% (20 oysters examined) were infected. Although Hopkins (1956a) has stated that heavy infections effectively castrate oysters and probably cause death, the worm was never found in epidemic numbers in Apalachicola Bay and the overall effect was probably of minor importance.

Several investigators have found that mudworms, *Polydora websteri,* damage oysters (Lunz, 1940, 1941; Mackin and Cauthron, 1952; see also Owen, 1957). Mudworms were fairly abundant at all stations, with the largest numbers at Station II, with as many as 20 *Polydora* blisters per oyster, covering an estimated 50% of the inside surfaces. The infestations found during the present study were not so severe as commonly found by investigators in South Carolina and Louisiana. It is concluded that mudworms did not cause oyster mortality directly.

Stone crabs, *Menippe mercenaria,* are serious predators of oysters (Menzel and Hopkins, 1955). No detailed analysis was made of all the dead oysters, but broken shells, indicative of stone crab predation, were seen at all localities. No satisfactory quantitative sampling method was devised for this burrowing crab, but it is estimated that up to one large crab (carapace over 75 mm wide) was present per square meter at Stations I and III. Sometimes up to a dozen small crabs (carapace under 50 mm wide) were found per square meter at these stations. Up to five small stone crabs (carapace les sthan 20 mm wide) were found in the two baskets examined monthly at Station III. Stone crabs were recorded from Station II up to the January 1956 examination, but were never found after this date. They disappeared after the first recorded salinity drop, even though higher salinities were recorded subsequently in May, June, and July, 1956. This is an indication that stone crabs are not tolerant of low salinities. Past observations by the senior author in Louisiana indicated that the stone crab is limited by salinities below 12-15 o/oo. Stone crabs were probably one of the main enemies of oysters, especially at Station III.

Blue crabs, *Callinectes sapidus,* were usually abundant, except in the coldest months, even though actual numbers were not recorded because of the sampling method. Lunz (1947) found blue crabs to be important oyster predators in pond culture in South Carolina. Menzel and Hopkins (1955) and Menzel and Nichy (1958) showed that they destroy small oysters and sometimes larger ones. Menzel and Nichy found that blue crabs destroyed oyster on intertidal reefs when the oysters were weakened by high temperatures. Blue crabs were probably a factor in the mortality observed in this investigation, especially on the middle of the reef at Station I.

The snail *Odostomia impressa* was present at all stations and was especially common at Stations II and III (high and low salinity stations). Salinity evidently was not a limiting factor in the area under study. Hopkins (1956b) found that *O. impressa* feeds on large oysters and Allen (1958) mentions oysters, other mollusks, worms, and ascidians as food. No detailed examinations were made of the damage caused by the gastropod and it was not possible to relate the oyster mortality to the abundance of the snail.

The crown conch *Melongena corona* at times was a conspicuous element on the oyster reef at Station I and has been observed with the proboscis inserted into oysters. Gunter and Menzel (1957) first recorded the crown conch as an oyster predator. Hathaway (1957) and Menzel and Nichy (1958) concluded, however, that it is an oyster enemy of minor importance in this area. This gastropod has been discussed more recently by Hathaway and Woodburn (1961).

The boring clam *Martesia smithi* does not feed on the oyster, but uses the shell as a habitat as do boring sponges and mudworms. Boring clams were most abundant at Station II in larger oysters. No correlation could be made with mortality or the condition of the oysters, although a more thorough investigation might reveal such association.

The southern oyster drill *Thais haemastoma* has been called the most serious oyster enemy in the Gulf of Mexico region (Butler, 1954). Mackin (1951b) states that where the drill occurs in abundance, along with the fungus parasite, *Dermocystidium marinum,* the drill probably causes a higher proportion of the oyster mortality. The drill was abundant at Station III (Figure 7), but was found at no other station except for one drill at Station I. The importance of the drill as an oyster enemy at Station III has been discussed by Menzel, Hulings and Hathaway (1957). The basket experiments at this station pointed strongly to predation as the cause of depletion of this reef.

At Station III there were numerous *Thais* egg cases during the season of 1956, but none was found in the spring of 1957. Even more noteworthy is the fact that no small snails were collected in any of the samples. It appears from the sizes and the fouled and eroded appearance of the shells that all the snails were more than one year old. Growth rate of drills in this particular area is unknown. Ingle (1951b) found that drills increased 12.2 mm in height in 82 days at Coral Gables, Florida. Butler (1953) found that they can reach a height of 55 mm in five months after hatching; however, he found that some six-month-old drills were larger than those that were thirty-six months old. This would imply that some three-year-old drills are under 60 mm. The maximum age attained by the drill is not known. In the present study the average size as well as the ranges in size were about the same for the first year's observations as for the second (Figure 7). The most likely explanation is that the drills on the reef were adult and were growing only slowly.

It is evident from the lack of small drills that there was no recruitment from the surrounding population during the two years of the study. The reef was re-sampled on October 8, 1957, when the bottom salinity measured 8.5 o/oo, and a search of several square meters revealed one live drill buried under several centimeters of shells. This was an adult snail (ca. 60 mm in height) and the operculum was tightly closed.

It is probable that a population of snails became established on

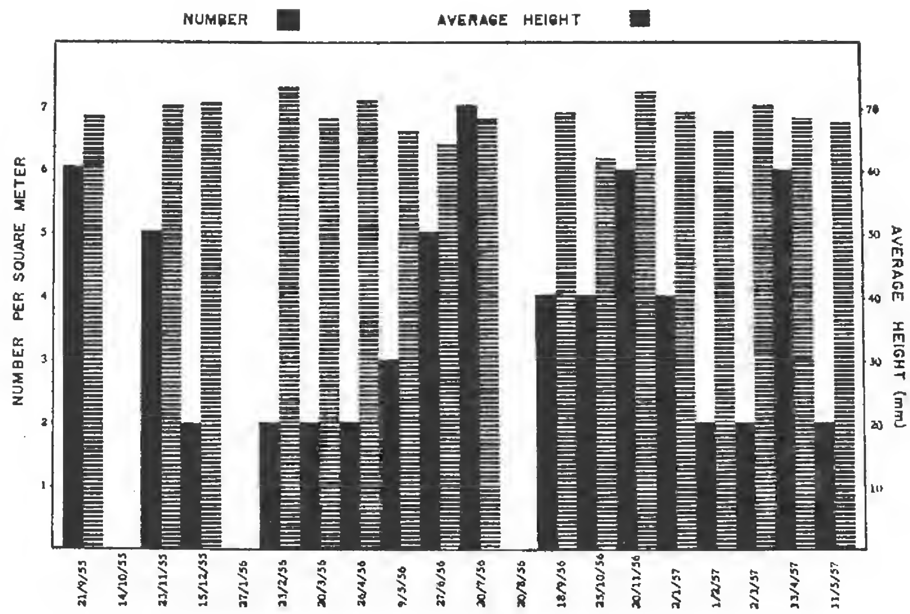


Figure 7. Numbers and average heights (mm) of *Thais haemastoma* per square meter during sampling period. Range in size from 52 to 84 mm.

this station when the salinity was favorable for them. Adult snails probably survived the occasional lowering of salinity by closing the opercula. Butler (1953) found the snail to be limited by an average salinity below 15 o/oo.

In addition many of the sessile animals that occur on an oyster reef probably have an adverse effect on oysters, especially in competition for food and space. For example, Engle and Chapman (1951) found that heavy attachment of mussels adversely affected the conditions of oysters.

At the two high salinity stations, the oyster *Ostrea equestris* occurred. This species was often very abundant at Station III, sometimes making up half of the numbers of oysters. It was found in small numbers on the extreme lower edges of the reef at Station I. Menzel (1955) has shown that *O. equestris* is stenohaline and also that it is subtidal. It is noteworthy that *O. equestris* had disappeared entirely from Station III on the May 11, 1957 examination, nor were any found when the reef was re-sampled in October 1957.

The two species of hooked mussels (*Brachidontes exustus* and *B. recurvus*) are fairly good salinity indicators. *B. exustus* is confined to fairly high salinity, *B. recurvus* is more euryhaline (although it was less abundant at Station III than at Station II, Table 5). The mud crab, *Neopanope texana,* was more abundant at the higher salinity stations and the same was true for the flat crab, *Petrolisthes armatus* (Table 5).

Some of the animals seemed to be limited more by other factors, such as bottom types and depth of water, than by salinity. *Anachis obesa* was more abundant at Station III than II, but it did not occur at Station I, perhaps because of the mud bottom, or the water depth, or both (Table 5). *Mulinia lateralis* was the only animal recorded exclusively from Station II, but its absence from other stations was probably due to factors other than salinity, since Simmons (1957) found this species in the Laguna Madre, Texas where the salinity is greater than normal oceanic waters.

Gunter (1955) has shown that in Texas waters the mortality of oysters increases over a rising salinity gradient from the inner bays towards the sea. Our own studies show that oyster mortality at a given station increases as the salinity rises following dry weather conditions. Both studies lead to the conclusion that the euryhaline Virginia oyster is strongly affected by salinity changes, indirectly through salinity influences on its predators and parasites. Grave (1905) has previously noted that oysters are subject to greater predation and parasitism at higher salinities.

Special Study of Station III

The reef at Station III formerly produced market oysters, but it had become depleted in the five years or so before the present investigation. A detailed report has been given by Menzel, Hulings and Hathaway (1957) of this station. Previous data on hydrographic conditions in the bay indicate generally lower salinities in the past than were found in this study (Table 2). The probable cause of the depletion of oysters at Station III was predation by animals with higher salinity requirements than oysters, notably stone crabs and drills. There was abundant spatfall. Some oysters, which were protected from large predators, reached a length of over 70 mm by the early spring of 1957 in contrast to unprotected oysters that were never larger than 50 mm in length (Figures 5, 6).

Station III was re-sampled on October 8, 1957. At this time one basket was recovered which had been left from the experiment begun in May 1956. In addition a random bottom sample of 24 liters was taken. The maximum size of the oysters found on the bottom and in the basket was no greater than it had been the previous spring. Rainfall had been continuous and rather heavy during the summer of 1957 and the salinity had undoubtedly remained low. The absence of *Ostrea equestris* and the presence of only one live *Thais haemastoma* with tightly closed operculum (12 dead shells found) corroborate the above statement. The salinity at the time of sampling in October 1957 was 8.5 o/oo.

From the evidence, predation during the summer period of 1957 may be largely discounted. The oysters should have reached larger sizes during this period than they had attained the previous spring. Because of growth, this reef should have supported a commercial fishery by the winter of 1957-58. It was predicted by Menzel, Hulings and Hathaway (1957), that with a return to normal rainfall, that the reef would become productive. St. Vincent Reef did become productive again, but no oysters of commercial size were obtained until the fall of 1958, one year later than expected.

SUMMARY

1. A study was made of three oyster reefs of differing ecological conditions in Apalachicola Bay area during the period from June 1955 through May 1957. Periodic quantitative samples of oysters and associated macroscopic organisms were taken, with particular emphasis on known oyster enemies.

2. Samples were taken at approximately monthly intervals during the first year at all stations and during the second year, one station (subtidal with high salinity) was sampled monthly and the other two seasonally.

3. During the second year some oysters were protected from two of the known enemies, drills and stone crabs, by wire baskets at the station (III) with high salinity that was sampled monthly. The protected oysters showed less mortality and reached a greater size than the unprotected oysters at this station.

4. The numbers sizes and mortality of oysters and of the associated animals differed from station to station and could be correlated with salinity, the past salinity regime, type of bottom and depth of water.

5. Salinity seemed to be the most important limiting factor on the oyster populations, but the strongest influence is indirect in that low salinity precludes the presence of important predators. The overall salinity increased shortly before the present study, correlated with an extended drought, and allowed certain oyster enemies less resistant than oysters to euryhaline conditions to become established on reefs. The depletion of a formerly productive reef occurred when the enemies became established. With increased rainfall and lowered salinities, the reef regained its former productivity.

ACKNOWLEDGEMENT

The writers thank Dr. Philip A. Butler, Bureau of Commercial Fisheries and the Florida State Board of Conservation for aid and suggestions.

LITERATURE CITED

Allen, J. Frances. 1958. Feeding habits of two species of *Odostomia* Nautilus, July: 11-15.

Butler, P. A. 1953. The Southern oyster drill. Proc. Natl. Shellfish. Assoc., 44: 67-75.

———————— 1954. Summary of our knowledge of the oyster in the Gulf of Mexico. U. S. Fish. Bull., 89: 479-489.

Danglade, E. 1917. Conditions and extent of the natural beds and barren bottoms in the vicinity of Apalachicola, Florida. Rept. U. S. Comm. Fish. for 1916. App. V: 1-68.

Dawson, C. E. 1955a. A contribution to the hydrography of Apalachicola Bay, Florida. Publ. Inst. Mar. Sci., IV(1): 12-95.

———————— 1955b. Observations on the incidence of *Dermocystidium marinum* in oysters of Apalachicola, Florida. Texas Journ. Sci. VII(1): 47-56.

Engle, J. B. and C. R. Chapman. 1951. Oyster condition affected by attached mussels. Proc. Natl. Shellfish. Assoc., 42: 9 pp.

Grave, Caswell. 1905. Investigations for the promotion of the oyster industry of North Carolina. Rept. U. S. Comm. Fisheries 29: 247-341.

Gunter, G. 1942. Seasonal condition of Texas oysters. Proceedings and Transactions of the Texas Academy of Science, 26: 53-54.

———————— 1955. Mortality of oysters and abundance of certain associates as related to salinity. Ecology, 36(4): 601-605.

Gunter, G., C. E. Dawson and W. J. Demoran. 1956. Determination of how long oysters have been dead by studies of their shells. Proc. Natl. Shellfish, Assoc., 47: 31-32.

Gunter, G. and R. W. Menzel. 1957. The crown conch, *Melongena corona,* as a predator upon the Virginia oyster. The Nautilus, 70(3): 84-87.

Hathaway, R. R. 1957. The crown conch, *Melongena corona* Gmelin, its habits, sex ratios, and possible relationship to the oyster. Proc. Natl. Shellfish. Assoc., 48: 189-194.

Hathaway, R. R. and K. D. Woodburn. 1961. Studies on the crown conch, *Melongena corona* Gmelin. Bull. Mar. Sci. Gulf and Caribb., 11(1): 45-65.

Hopkins, S. H. 1956a. Our present knowledge of the oyster parasite, "Bucephalus". Proc. Natl. Shellfish. Assoc., 47: 58-61.

———————— 1956b. *Odostomia impressa* prasitizing Southern oysters. Science, 124(3223): 628-629.

Hopkins, S. H., J. G. Mackin and R. W. Menzel. 1953. The annual cycle of reproduction, growth and fattening in Louisiana oysters. Proc. Natl. Shellfish. Assoc., 44: 39-50.

Hyman, Libbie H. 1940. The polyclad flatworms of the Atlantic Coast of the United States and Canada. Proc. U. S. Natl. Mus., 89: 449-495.

Ingersoll, E. 1881. The oyster industry. U. S. Fish. Comm., 4: 1-252.

Ingle, R. M. 1951a. Spawning and setting of oysters in relation to seasonal environmental changes. Bull. Mar. Sci. Gulf and Caribb., 1 (2); 111-135.

———————— 1951b. Notes on the growth of *Thais haesmastoma floridana* and *Thais rustica.* Proc. Natl. Shellfish. Assoc., 42: 12-14.

Ingle, R. M. and C. E. Dawson. 1950. Variations in salinity and its rela-

tion to the Florida oyster. Salinity variation in Apalachicola Bay Proc. Gulf and Caribb. Fish Inst., 3: 35-42.

————————. 1952. Growth of the American oyster, *Crassostrea virginica* (Gmelin), in Florida waters. Bull. Mar. Sci. Gulf and Caribb., 2(2): 393-404.

————————. 1953. A survey of Apalachicola Bay, Florida, State Board of Conservation. Tech. Ser. 10.

Lunz, G. R. Jr. 1940. The annelid worm, *Polydora,* as an oyster pest. Sci. 92: 310.

————————. 1941. Polydora as an oyster pest in South Carolina water: J. Elisha Mitchell Sci. Sco., 57: 273-283.

————————. 1947. *Callinectes* versus *Ostrea.* J. Elisha Mitchell Sci. Soc., 63: 81.

Mackin, J. G. 1951a. Incidence of infection of oysters by *Dermocystidium marinum* in the Barataria Bay area of Louisiana. Proc. Natl. Shellfish. Asso., 42: 22-35.

————————. 1951b. Diseases of oysters and their relation to the Gulf Coast oyster industry. Proc. Gulf and Caribb. Fish Inst., 3: 24 (abstract).

————————. 1952. Histopathology of infection of *Crassostrea virginica* (Gmelin) by *Dermocystidium marinum* Mackin, Owen and Collier. Bull. Mar. Sci. Gulf and Caribb., 1(1): 72-87.

Mackin, J. G. and F. F. Cauthron. 1952. Effects of heavy ionfestations of *Polydora websteri* Hartman on *Crassostrea virginica* (Gmelin) in Louisiana waters. Proc. Natl. Shellfish. Assoc., 43: 14-24.

Menzel, R. W. 1955. Some phases of the biology of *Ostrea equestris* Say and a comparison with *Crassostrea virginica* (Gmelin). Publ. Inst. Mar. Sci., IV(1): 69-153.

Menzel, R. W. and S. H. Hopkins. 1955. Crabs as predators of oysters in Louisiana. Proc. Natl. Shellfish. Assoc., 46- 177-184.

Menzel, R. W., N. C. Hulings and R. R. Hathaway. 1957. Causes of oyster depletion in St. Vincent Bar, Apalachicola Bay, Florida. Proc. Natl. Shellfish. Assoc., 48: 66-71.

Menzel, R. W. and F. E. Nichy. 1958. Studies of the distribution and feeding habits of some oyster predators in Alligator Harbor, Florida. Bull. Mar. Sci. Gulf and Caribb., 8: 125-145.

Moore, H. F. 1897. Report of the specimens collected from the oyster beds of St. Vincent Sound, Apalachicola Bay and St. George Sound, Florida, during the winter of 1895-96. Rept. U. S. Comm. Fish. for 1896: 218-221.

Owen, H. M. 1957. Ethiological studies on oyster mortality. II *Polydora websteri* Hartman - (Polychaeta: Spionidae). Bull. Mar. Sci. Gulf and Caribb., 7(1): 35-46.

Pearse, A. S. and G. W. Wharton. 1937. The oyster "leech", *Stylochus inimicus* Palombi, associated with oysters on the coasts of Florida. Ecol. Monogr., 8: 605-655.

Ray, S. M. 1954. Biological studies of *Dermocystidium marinum,* a fungus parasite of oysters. Rice Institute Pamp., Special Issue. 1-114.

Simmons, E. G. 1957. An ecological survey of the upper Laguna Madre of Texas. Publ. Inst. Mar. Sci. (Univ. Texas), IV(2): 156-200.

Swift, F. 1897. Report of a survey of the oyster regions of St. Vincent Sound, Apalachicola Bay and St. George Sound, Florida. Dept. U. S. Fish. Comm. for 1896: 187-217.

Gulf Research Reports

Volume 2 | Issue 2

January 1966

Habits of Juvenile Fishes in Two Rhode Island Estuaries

Mohammed Saeed Mulkana

The Growth And Feeding Habits of Juvenile Fishes In Two Rhode Island Estuaries

by

MOHAMMED SAEED MULKANA

TABLE OF CONTENTS

ABSTRACT

The basic purpose of this work was to gain information on the possible role of some Rhode Island estuaries as nursery grounds for young migrant and resident species of fishes.

The areas selected were, the lower Pettaquamscutt River and the lower Point Judith Pond, both in the town of Narragansett, Rhode Island. The seining operations were carried through summer and early fall of 1962 when these estuaries are heavily used as nursery grounds. Major features of the occurrence, abundance and distribution of young fishes were deduced by examining samples from seine hauls. Thirty-six species were recorded from the lower river while only twenty-four species occurred in the lower pond. The abundance of fishes rose with a rise in temperature and declined with decreasing temperature, but no correlation was observed between maximum temperature and maximum number of individuals occurring at any time. The number of species and the abundance of individual fish were highest at the seaward station (Sta. II) in the lower river. Among the selected species, the abundance of Menidia menidia *was two to three times higher at Middle Bridge (Sta. II) than at any other station. The behavior of* Pseudopleuronectes americanus, *found primarily at seaward stations, and the migrant species* Brevoortia tyrannus *observed at landward stations, is discussed.*

The species P. americanus *grew at the rate of 10 mm per month, but exhibited no variation in growth in the two estuarine systems. The populations of* B. tyrannus *from the lower Pettaquamscutt River had a growth rate that was almost twice that of populations in the lower Point Judith Pond. The growth rate of these species in Rhode Island waters compare favorably with similar data from other studies. The juvenile* M. menidia *demonstrated a higher rate of growth at seaward stations in both the areas, especially in the lower river.*

Forty-three types of prey organisms belonging to diverse taxonomic groups were identified from stomach contents of P. americanus *and thirty-nine types were noted in the gut contents of* M. menidia. *Analysis of the degree of fullness indicated markedly high percentage of full stomachs in the two study areas. However the degree of fullness was comparatively less in fish occurring in the lower pond. The scarcity of food in the lower pond, apparently forced* M. menidia *(51-80 mm) to feed upon phytoplankton as a substitute food or "forced diet". In* P. americanus *and* M. menidia *a change in diet was noted with change in size. The taxon,* B. tyrannus, *which depended upon phytoplankton and suspended organic matter, did not show any change in food with change in body size.*

While no effective predation was observed, an infection by the sporozoan parasites, Glugea hertwigi, *was marked in both* Osmerus mordax *and* P. americanus. *Low catches of* P. americanus *were perhaps due to higher infection.*

A comparison of the parameters of abundance, growth and food habits reveal that the two estuarine systems are suitable nursery grounds, and that the lower river is a more favorable nursery than the lower pond.

LIST OF FIGURES

LIST OF TABLES

I. INTRODUCTION

The purpose of this work was to evaluate selected Rhode Island estuaries as nursery grounds for juvenile fishes. The juvenile stage in the life history of fishes follows the emergence from larval life to an independent young phase. At this stage survival becomes dependent on physiological and morphological fitness, availability of suitable types of food, and protective adaptations to minimize predator and parasite invasion and over-population pressure. The immature young of coastal and offshore fishes of many species spend their critical juvenile period in protected, food-rich estuaries. Often the success of stocks in a fishery is dependent on the presence of areas suitable as nursery grounds.

Greely (1939), Warfel and Merriman (1944) and Pearcy and Richards (1962), who studied the seasonal variations and ecology of juvenile and adult fishes along the New England Coast, and Shuster (1959) who conducted similar investigations in Delaware Bay estuaries, all reported a great abundance of fish-of-the-year of various species in the shallow waters of coastal ponds, estuaries, and bays. Fish's (1938-42 unpubl.) observations in Rhode Island waters point to the same conclusions. Information from all of these sources provides strong evidence that estuarine environments play a vital role in the survival and maintenance of stocks of the coastal and offshore fisheries of commercial significance.

The present work is an attempt to gain information on the role of two estuaries in Rhode Island as nursery grounds for young fishes of coastal and offshore species. Emphasis was laid on the seasonal changes of young fish populations with respect to their total and relative abundance and distributional patterns. An idea of the success of these estuaries as nurseries was gained through growth studies and analyses of the feeding habits of three species, the winter flounder, *Pseudopleuronectes americanus,* the Menhaden, *Brevoortia tyrannus,* and the Silversides, *Menidia menidia.* These species in general are benthic, pelagic and omnivorous respectively in behavior and food habits. The diverse feeding habits should provide information on the overall available food present in an environment. The average growth rate of these species should be a function of the success of the feeding niches occupied by these species.

The coast of Rhode Island has a series of salt ponds and estuaries lying both parallel and perpendicular to Rhode Island and Block Island sounds. By definition (Emery *et. al.,* 1957) coastal ponds or lagoons are former embayments which have been partially isolated from coastal waters by barrier sand bars. Some estuaries, especially along the shores of southern New England, represent drowned glacial outwash stream valleys. Rochford (1951) described estuaries as bodies of water in which chlorinity and salts and other properties are subjected to an alteration by inflow of fresh water and sea water in certain ratios during the tidal cycle. Further there exists a persistent circulation and exchange between the estuarine system and adjoining neritic waters.

The present studies were conducted in certain areas of the Pettaquamscutt River and Point Judith Pond estuaries in the town of Narragansett, Rhode Island (Fig. 1 and 2). The area under study in the lower Pettaquamscutt River lies within a "gradient zone", a zone having a distinct salinity gradient. The seining stations in Point Judith Pond were

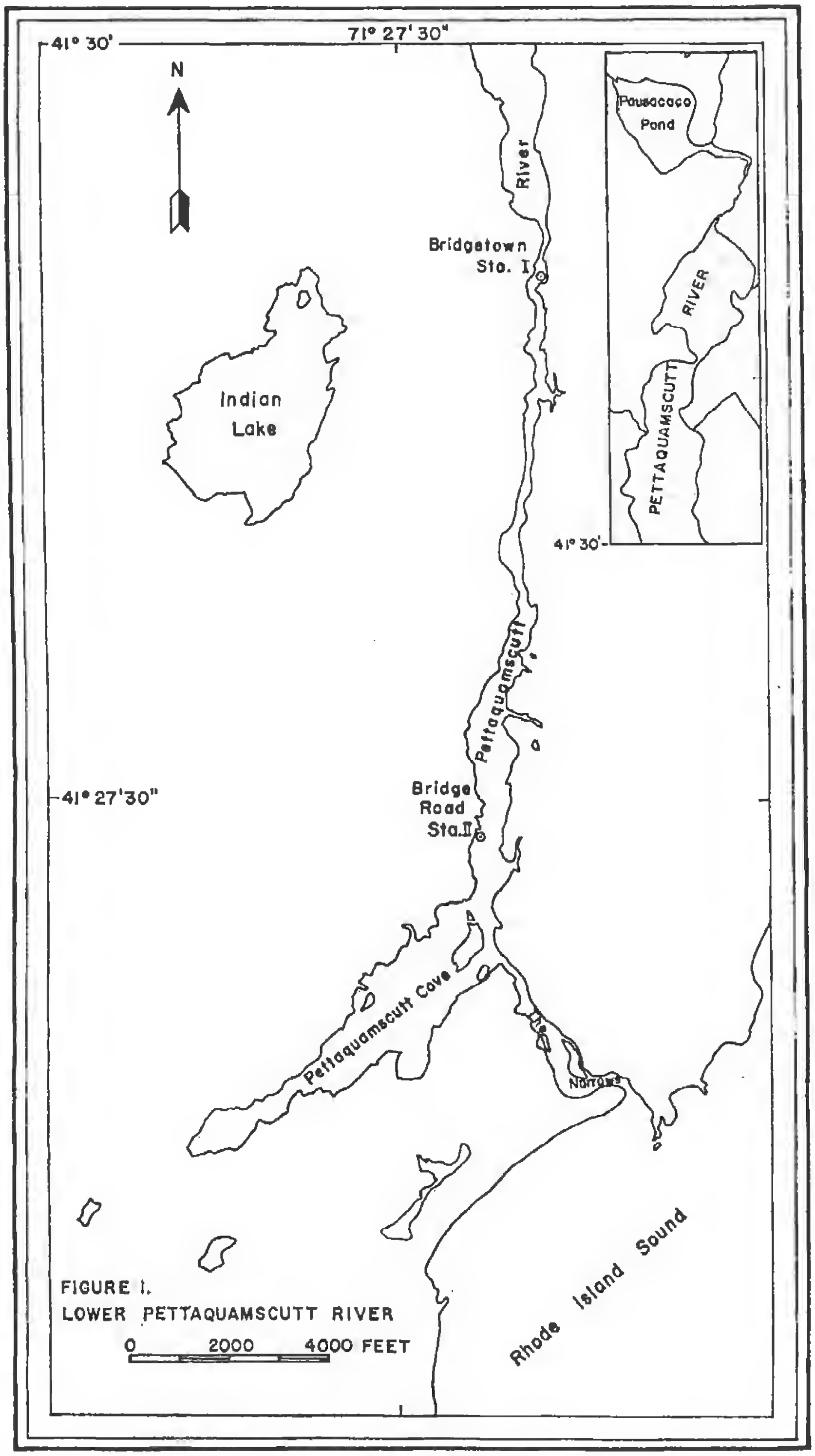


Fig. 1. Map of Pettaquamscutt River Estuary showing location of seining stations.

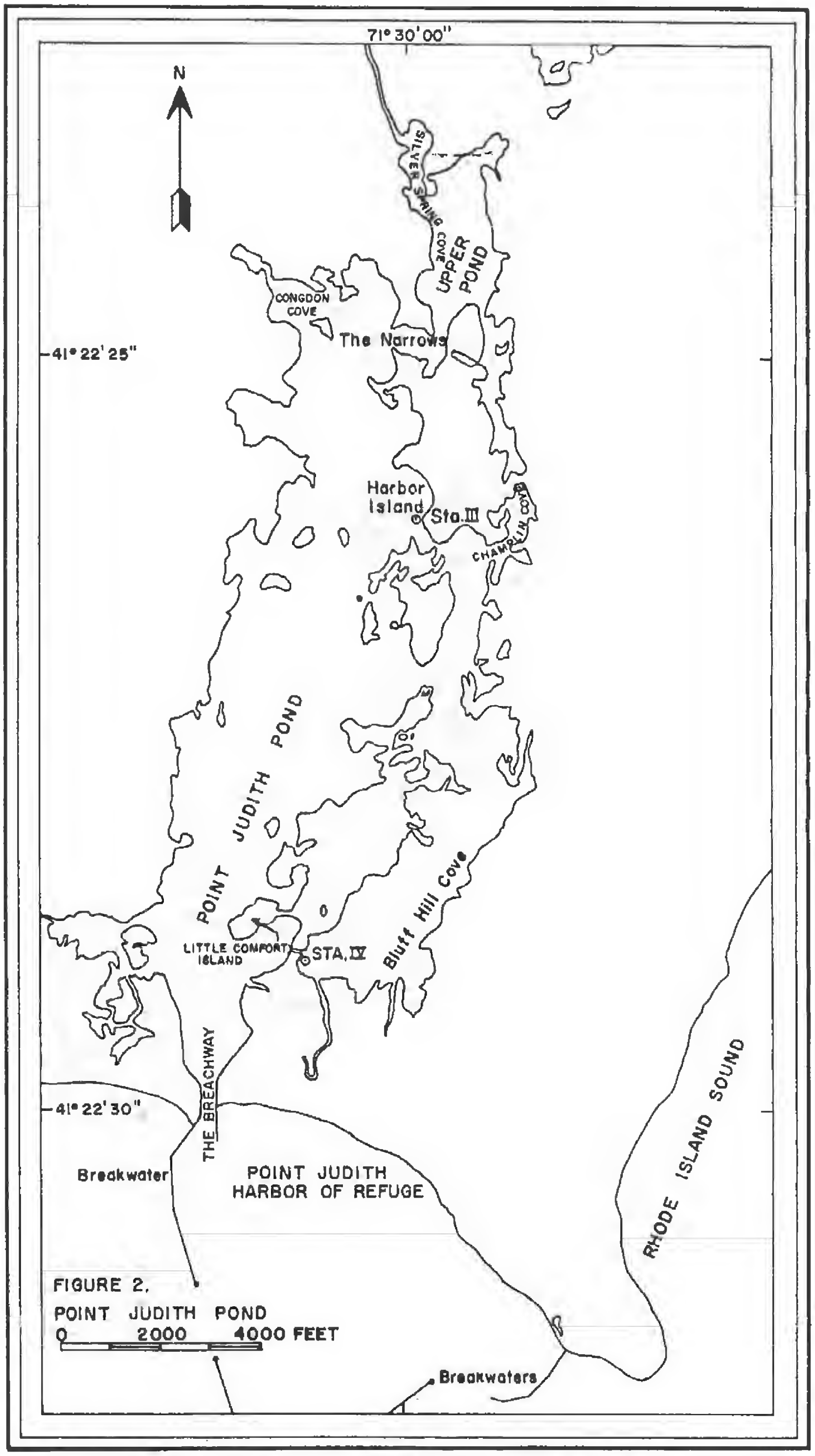


Fig. 2. Map of Point Judith Pond Estuary with locations of seining stations.

located in the lower pond, characterized as the "marine zone" according to Rochford (1951) where near-neritic conditions exist.

The river estuaries are generally considered more productive than coastal ponds and lagoons (Riley, 1937; Rochford, 1951 and Emery *et al.*, 1957). Consequently the diverse environmental conditions existing in the two estuarine systems should provide an opportunity to study the variations in abundance, average growth of young fishes and the available food in the particular feeding niches of selected species of fishes. In describing the overall occurrence and abundance of juvenile fishes some parameters for the adults of some of the smaller resident species also were included. These fishes though of no direct commercial importance, play a significant role as a food supply, as special competitors and as predators for other juvenile species of economic significance in the estuaries.

II. REVIEW OF LITERATURE

Fluctuations in fish populations have been an important concern to man since neolithic times. The pursuit of knowledge through biological investigations long remained directed towards the study of adult fishes.

Early studies by Jordan (1896-1900) in North and Middle America, Smith's (1898) investigations in the Woods Hole region, and Tracy's (1906, 1910) work in Rhode Island water all pertain to the occurrence and systematics of regional fish fauna. Quantitative studies of young fish started recently in these areas.

Hjort (1926) theorized that the numerical prominence of a year class is determined at a very early stage. Hjort's early methods and attempts to determine spawning and nursery areas brought him to the conclusion that fishes early in their life histories tend to localize in particular ecological habitats. Greely's (1939) investigation in the estuaries, creeks and oceanic inlets in Long Island Sound during the summer led him to assume that these environments may not constitute spawning areas for various species but are important rearing grounds for young fishes from remote spawning centers.

The results of the analysis of seasonal abundance and distributional patterns of young and adult fishes by Warfel and Merriman (1944) in southern New England waters point to the direct influence of temperature on immigration and emmigration of migrant species. The results manifest that factors like population density, age, depth and meterological conditions probably determine the distribution of young fishes. Adolf (1925) found that marine organisms can tolerate drastic changes in the osmotic environment more effectively than fresh water forms. Horton (1958) observed strictly marine forms in fairly brackish water environments in the upper reaches of the Pettaquamscutt River, Rhode Island, indicating that young marine immigrant species may successfully thrive in all of the salinity regimes in an estuary. Based upon the ecological studies of larvae, juvenile and adult fishes of the Mystic River estuary, Pearcy and Richards (1962) contended that estuaries may be important as spawning grounds, nurseries for juvenile fishes and feeding grounds for adult forms of resident and migrant species.

Hiatt and Strasbury (1960) analysed the relationship for 233 species of fishes in many diverse types of ecological niches in the coral reefs of the Marshall Islands. Their description of feeding types illustrates the

feeding habits and food requirements of fishes that utilize energy from different trophic levels. While this detailed study attempted to explain self-adjusted steady state equilibria existing in great varieties of reef habitats, the principles deduced may also be applicable to ecosystem studies in estuarine environments. Richards (1963) studying the feeding ecology of juvenile fishes in Long Island Sound, indicated that sporadic immigration of migrant species may not cause interspecific competition if superabundant and well distributed food is present. Richards suggested that the mobility of prey and predator species common in a temperate marine environment, such as Long Island Sound, is an important factor indicative of the success of the various feeding niches. Ivlev's (1954a) investigation on the ecology of the feeding habits of fishes showed that with an increase in available food, the daily ration approaches a maximum ration. The application of this principle suggests that in an environment with ample food, young fishes are attracted whose fast early growth may require large quantities of food. Ricker (1946) reports that small fish eat more per unit body weight than large fish, hence the rate of feeding could affect the size of the fish. Pearcy (1962) conducted studies on the quantitative aspects of abundance, growth, survival and mortality of larvae and juvenile stages of *Pseudopleuronectes americanus* in the Mystic River Estuary. Comparing the biomass and productivity measurements of the Mystic River Estuary with that of Long Island Sound, he concluded that some estuaries are more productive than some neritic environments and serve as nursery areas for young fishes. Shuster (1959) working on the biological evaluation of the Delaware River Estuary points out that estuaries are important spawning and nursery areas and contribute effectively to the economy of the coastal fisheries.

III. METHODS AND MATERIALS

Stations:

The selection of the stations was based upon Fish's results (1938-42 Unpubl.) of seining operations in the lower Pettaquamscutt River and certain other ponds and estuaries in Rhode Island, easy access from the shore and maximum seining area available with practicable depth. Two stations were established in the lower Pettaquamscutt River and in the lower Point Judith Pond about three kilometers apart (Figs. 1, 2). The seining operations were carried out in the lower Pettaquamscutt River at the Bridgetown Bridge (Station I), and at the Middle Bridge (Station II); and in lower Point Judith Pond at Harbor Island (Station III) and at Galilee (Station IV). For brevity in the following account the study areas in each of the estuaries will be referred to as "lower pond" (lower Point Judith Pond) and "lower river" (lower Pettaquamscutt River).

Seining Operations:

Seining was carried out at selected stations only during the ebb tide. A fifteen-meter-long, shore seine with quarter-inch (6.4 mm) mesh was employed. Within the center of the seine a square of 1 mm mesh netting (2m x 2m) was fastened to ensure capture of small fishes. The seine was fished parallel to the shore from low water mark to a point 15m perpendicular to the shore, and was swept for 15m in either direction. At the end of each seine haul a capture arc was formed and the lower weighted end was drawn first thus pursing the seine to retain the catch. A strictly identical seining procedure was followed throughout the survey period. From the seine hauls numerical abundance of all species was noted.

Preservation:

A subsample of at least thirty randomly selected specimens of the more abundant species of fishes were retained for further analysis. The fishes were placed in 2% formalin. The formalin concentration was slowly increased to 10%. The procedure allowed the formalin to diffuse into the alimentary tract to stop further digestion and subsequent decomposition of the gut contents. Abdominal cavities of some fishes of selected species were incised before final preservation. The formalin was saturated with sodium tetraborate ($Na_2B_4O_7$) or calcium carbonate ($Ca\ Co_3$) to neutralize the acid and to keep the gut contents softened for identification.

Temperature:

Surface water temperature was measured at each station weekly 5 meters from the shore during ebb tide using a mercury thermometer to the nearest 0.2°C.

Salinity:

Surface and bottom salinity was determined by a conductivity method each week, using an electronic salinometer designed and built by J. T. Conover. Bottom water samples were taken with a sampler consisting of a polyethylene tube stoppered at both ends and equipped with a glass tube at the lower end.

The salinity of a series of surface and bottom water samples was determined along the north-south axis of both estuaries at ebb and flood tides, during one 24-hour tidal cycle on July 21, 1963. From these data salinity ratios during a complete tidal cycle were computed to aid in the zoning of the estuaries after Rochford (1951).

Precipitation:

Rainfall data were obtained from the Monthly Climatological Summary of the New England Region compiled by the U. S. Weather Bureau. The rainfall recorded by the Weather Bureau at the Hillsgrove Municipal Air Port in Providence, was used for both estuaries.

Identification and Counts:

Fishes from each sample were identified and counts were recorded and used to determine total and relative abundance. Two species, *Pseudopleuronectes americanus* and *Brevoortia tyrannus,* which occurred in significant numbers and have economic importance, and a most abundant small species, *Menidia menidia,* were selected for a detailed study. These fishes have diverse food habits and provide a good trophic picture of the environment.

Age Groups:

The separation of the young of the zero plus class of *P. americanus* and *B. tyrannus* presented no problem since the criterion of standard length, distance from snout to hypeural plate alone, is a reliable tool to distinguish zero group from older groups in these species (Pearcy, 1962, and McHugh *et al.,* 1959). To confirm this assumption for *P. americanus* in the separation of age groups, scales and otoliths were examined following the annulus interpretation given by Welsh (1924), Berry (1959) and others. For an interpretation of scales of *B. tyrannus* the writer followed criteria laid down by Hile (1948), Westman and Nigrelli (1955) and McHugh *et al.* (1959). No reliable information is available for the exact size range of the zero age group for *Menidia menidia.* Williams (1960)

considered fish of second year class as above the minimum size of 50 mm. The juvenile fish could be distinguished during early summer, but in late summer and fall an admixture of young and adult fish of overlapping size groups made it impossible to distinguish the young from the adults. The data were analysed by a graphical method (see below) which gives the size range and demonstrates the possible growth in such groups.

Growth Computations:

In view of marked fluctuations in the sample sizes of the selected species, the data were processed and computations made using an improved graphical method by Hubbs and Hubbs (1953) based upon an analysis of variance. Graphical analysis demonstrates the significance of differences between the series of samples as well as the degree of reliance on the results. The average values of standard lengths for the selected species were used to draw growth curves. For complete detail see legend for figure 13.

Food Analysis:

The food study was based on an analysis of stomach contents. It is, however, important to couple such studies with a determination of the types and abundance of food present in the environment. Due to the preliminary nature of the present work and to the time factor only stomach contents were considered in this study.

The food present in a stomach is in a less advanced state of digestion than in the intestine and permits better identification. In the absence of a well defined stomach as in the case of *Menidia menidia,* gut contents were used for food analysis. The following methods were employed for food study:

1) The occurrence method determines the palatibility of food (Allen, 1935 and Hartley, 1947).

2) The average stomach content method demonstrates the relative importance of individual prey species (Covill, 1959 and others).

3) The fullness method is a special extension of total volume method and estimates variation in quantity of food in various size groups, areas and seasons.

The size of each food organism was also measured using an ocular micrometer. All collections of each selected species from each estuary were combined, and a sample of 150 fish was taken randomly for food analysis. Fishes were categorized in three arbitrary size groups to find variations in food with respect to sizes of fishes. A fair number of stomachs or alimentary tracts from each size group, depending upon the number available, were individually dissected, the contents identified and counts made in a Sedgewick-Rafter cell or a larger improvised counting chamber under 60 X magnification. Later on stomachs or alimentary tracts were grossly studied in groups of ten. In the case of *Menidia menidia* collected from the lower Point Judith Pond, the volumes of gut contents of various size groups were determined. The gut contents which were comprised entirely of phytoplankton, were diluted, and from aliquots the number of organisms per cubic millimeter was determined.

IV. THE ENVIRONMENT

A. Topographic and Edaphic Features

1. Topography.

The Pettaquamscutt River Estuary represents a drowned river valley

in the post-glacial topography of a coastal plain. From its source at Pausacaco Pond in North Kingstown, the estuary extends southerly for 9 kilometers to its mouth which discharges into West Passage of Narragansett Bay. Near Sprague Bridge an arm of this estuary extends for 2.1 kilometers in a southwesterly direction ending blindly as the very shallow Pettaquamscutt Cove. The north-south axis of this estuary lies between latitude 41°26'N and 41°31'N and at longitude 71°27'30"W (Fig. 1). The river is 6 meters to 0.8 kilometers broad and has a narrow constricted mouth facing southeast. The interesting and unusual features of this estuarine system are the presence of two deep stagnant basins north of the Bridgetown Bridge which are separated from the rest of the estuarine system by shallow sills. These are kettle holes, filled with stagnant high-salinity water. Only the surface water, a few meters deep, undergoes a change in salinity during the tidal cycle. Mixing into the stagnant zone may occur when strong hurricane winds roil the river water (Jeffries and Smayda, 1954; Horton, 1958).

The Point Judith Pond is one of the largest salt ponds along the coast of Rhode Island, measuring 6.3 kilometers from the breachway at Block Island Sound to Silver Spring Cove and from 90 meters to 2.1 kilometers in width (U. S. Geological Survey, 1957). The boundaries are located between 41°22' and 41°27'N latitudes and 71°29' and 71°32'W longitudes (Fig. 2). The Saugatucket River drains into the upper Pond which opens through a narrow constricted passage, "The Narrows," into the considerably larger lower Pond. The flow of river in the lower pond is considerably less in camparison to the river inflow in the river estuary, since there is no significant salinity gradient in the greater part of the pond (Fig. 3). The lower pond is linked to Potter Pond through a narrow stream facing west and discharges southerly in Block Island Sound through the Point Judith Harbor of Refuge. The tidal flats, small coves, bars, shoals and islands are the chief topographical features in the pond estuary. Tidal amplitudes and currents in this estuary are strongly influenced by the presence of breakwaters, jetties and the irregularity of shore line and bottom contours.

2. Hydrographical Zones.

Based on the salinity conflict (modified from chlorinity conflict) after Rochford (1951), the estuaries were classified into various zones, following Rochford's assumption that ecological variations in these zones were characteristics of these environments in any estuary. Four zones were identified in the Pettaquamscutt River estuary.

a) "Marine Zone." The salinity ratio at ebb and flood observed during a tidal cycle was 1:1. According to Rochford (1951) the absence of a salinity conflict, a ratio of change, during a tidal cycle in an area helps categorize it as a "marine zone." This zone lies between the entrance from the West Passage to Sprague Bridge (Figs. 1 and 3).

b) "Tidal Zone." This zone marks the development of slight changes in salinity from ebb to flood tide and has maximum development of intertidal mud flats, and very shallow areas. The area between the northern boundary of Pettaquamscutt Cove to a kilometer towards Middle Bridge (Sta. II) has a salinity ratio of 1:1.1. In addition, Pettaquamscutt Cove having extensive intertidal mud flats, a characteristic feature of a tidal zone, may also be considered within the same domain.

c) "Gradient Zone." This zone demonstrates a maximum salinity conflict in this estuary, with a ratio of 2:3. The limits of this zone extend from the vicinity of Middle Bridge to the entrance of Gilbert Stuart Brook (Figs. 1 and 3). The lower portion of the river in this zone has a comparatively narrow channel, a characteristic feature of such a zone (Richford, 1951). The deep saline pockets, represented by kettle holes do not ordinarily disturb the gradient, since the water below the sills, a few meters deep, remains uninfluenced by the tidal cycle.

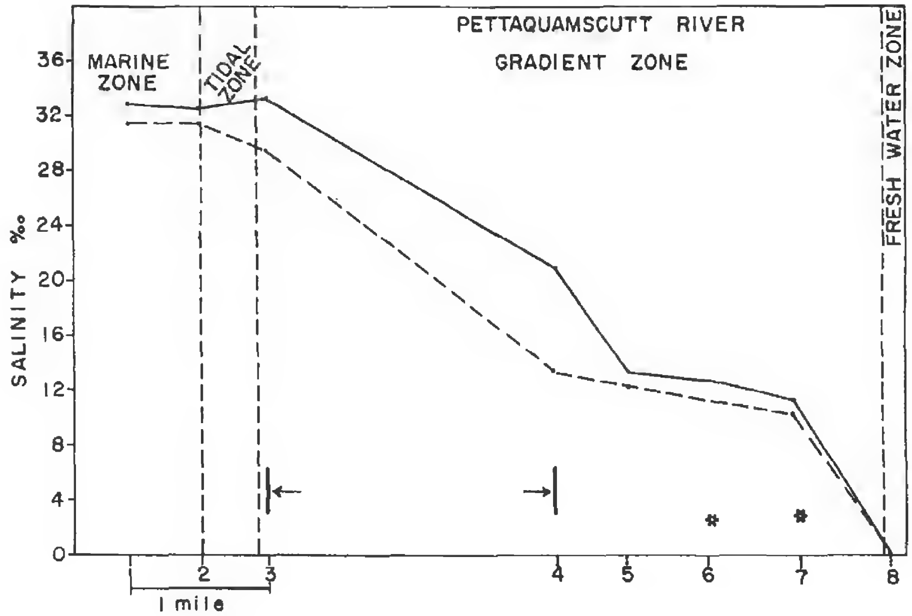
d) "Fresh Water Zone". No saline water is present in this zone. The entire Gilbert Stuart Brook system was considered as the fresh water zone (Fig. 3).

Only two zones could be defined in the lower Point Judith Pond. The area is dominated by the "marine zone." The salinity ratio found between ebb and flood tide was about 1:1, characteristic of this zone. In the Upper Pond the gradient and fresh water zones are present, but so constricted or small in area as to be of little importance to the estuary as a system. The lower pond however has a series of coves with well-developed extensive intertidal mud flats.

3. Edaphic and Biological Aspects.

Pettaquamscutt River. The area involved in this study lies within the "gradient zone" (Fig. 3) extending from Bridgetown Bridge (Sta. I) to Middle Bridge (Sta. II). The depth in the mid-channel at low tide is about 2 meters at Station I and 2.5 meters at Station II. The depth at the seining area of Station I varied between 0.6 m and 1.5 m. The depth at Station II was between 0.6 m and 1.2 m. McMaster (1958), in describing the bottom topography of the estuary from Bridgetown Bridge to Middle Bridge, indicated that the bottom near the Bridgetown Bridge is sandy with isolated patches of silty sand which changes to a mixture of soft silty sand and mud near the lower bridge (Sta. II). Sparse beds of *Zostera marina* occur near Bridgetown Bridge and increase in abundance down the river towards the lower station. South of Middle Bridge the bottom is composed of soft silty sand and thick stands of *Zostera marina.* The Eel grass becomes heavily epiphytized during the warm season.

The Lower Point Judith Pond. The seining stations located within the lower pond characterized as "marine zone" extend from the Bluff Hill Cove to Harbor Island (Figs. 2 and 3). The depth in this area varies between 0.6 m and 3 m. The depth at seining Station III, Harbor Island, varied between 0.6 m and 1.5 m, while at Galilee (Sta. IV) it was between 0.6 m and 1.2 m. Although the breakwater riprap minimizes the effect of waves, the north-south axis of the lower pond is markedly influenced by fast water circulation because of nearness to the open ocean. The bottom along the channel is rocky or sandy, except for inlets and coves. Along the east side of the lower pond, from Harbor Island southward, the bottom is lined with coarse sand, pebbles and cobbles especially near the shore lines of the islands centrally located in the pond basin. The Harbor Island Station has massive plant beds including *Entermorpha linza, Scytosiphon lomentaria, Ulva lactuca, Fucus vesiculosis* as well as minor plant species. The plants serve as a protection for young fish against predators and the epibiota are probably an important food source. At the lower extremity of Bluff Hill Cove (Sta. IV) the bottom consists of soft clayey silt with a high organic content which gives away to a silty sand towards the breachway. The plant life is sparse and the area is comparatively much shallower than that of the Harbor Island station (Sta. III).



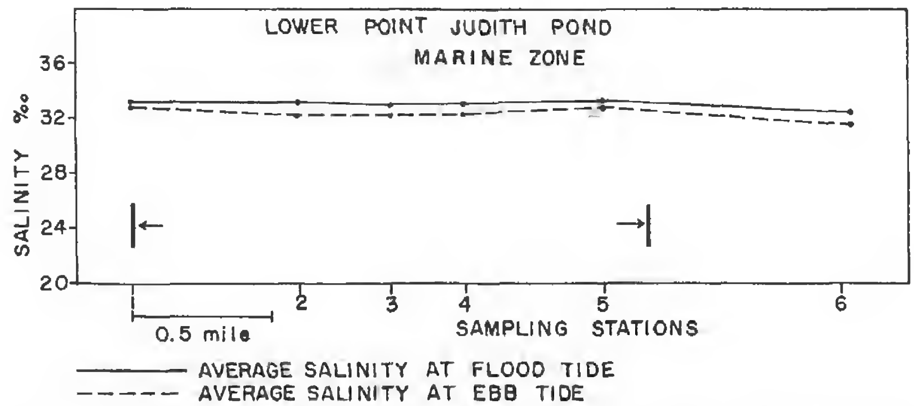


Fig. 3. Distribution of hydrographical zones in Pettaquamscutt River and the lower Point Judith Pond estuaries (after Rochford, 1951).

LEGEND FOR FIGURE 3.

The area between the arrows in each graph indicates the study areas in the two estuaries. The stations marked with asterisks represent deep basins separated from one another and from the rest of the estuary by shallow sills. The vertical salinity gradient below a few meters in depth demains stable, and stagnant conditions exist in these salt pockets (Jeffries and Smayda, 1954; Hicks, 1958). Data for the bottom water were taken from samples at three meters depth in these basins; consequently, the differences in the salinity ratios at ebb and flood tide were much smaller than they would have been if the high salinity water in the kettle holes had been considered. The water samples were taken on July 21, 1963, which had followed a long draught period (Climatological Data from New England Region, U. S. Weather Bureau). The salinity values shown are abnormally high as compared with average salinity data in these areas (Jeffries and Smayda, 1954; Hicks, 1958; Horton, 1958).

B. HYDROGRAPHY

1. Salinity.

A strong salinity gradient was observed in the lower Pettaquamscutt River, while conditions in the lower Point Judith Pond were almost neritic (Figs. 3 and 5). Considerable variations in salinity occurred especially in the lower river, the difference between 9.8 and 15.1 o/oo. The brackish water conditions exist at this station because of its nearness to a fresh water source. The range in salinity noted at the more seaward station (Sta. II) was highest, varying between 20.3 to 32.3 o/oo. The abrupt fluctuations in salinity were apparently caused by heavy precipitation during early September and October (Fig. 4). The rate of inflow of fresh water which depends upon seasonal precipitation is assumed to be the major factor influencing changes in salinity. Strong or hurricane winds very infrequently produce a significant increase in salinity by stirring up stagnant water from the upper basins (Jeffries and Smayda, 1954; Horton, 1958).

The Point Judith Pond estuary while it is narrow at the transition, the breechway, broadens considerably in the mid-region. The surface and bottom salinities in the lower pond, though not markedly diverse, indicate an apparent vertical stratification because of probable net non-tidal drift upstream at the bottom and net non-tidal drift downstream at the surface. The Point Judith Pond is a shallow estuary. Stommel and Farmer (1953) indicated possible overmixing in such estuaries, and suggested that salinity in the upstream is determined by the throttling action of the narrow transition. In the lower pond which covers three-fourths of the entire pond, the seasonal salinity variation never exceeded more than 2 o/oo at the two extremities (Sta. III and Sta. IV). The seasonal surface salinity at Harbor Island ranged between 28.5 to 31.5 o/oo. The narrow range and low variations compared with those observed in the lower Pettaquamscutt River suggest that the salinity regime of the lower pond is greatly influenced by neritic waters. Furthermore the fluctuations in salinity in the lower pond were also correlated with the precipitation (Fig. 5).

2. Temperature.

The surface temperature measured during summer and early fall at both stations in the lower river ranged between 23.8°C and 14.2°C. The temperature remained comparatively high in October at the Middle Bridge station perhaps because of the shoalness of the area (Fig. 6). The maximum temperature values were observed in August and the minimum in October.

The temperature in the lower pond maintained a fairly constant level until September 14. The seasonal range in temperature varied between 24.2°C to 14.2°C. The decrease in temperature was rapid from mid September to the last sampling date in October. Although the seaward station in the lower pond is shallower, no marked variation in temperature was apparent between the two stations (Fig. 6). The fast renewal of water, and near shore conditions may be factors in support of this constancy. The seasonal fall in temperature compared well with data from other New England estuaries such as Great Pond, Falmouth (Conover, 1958).

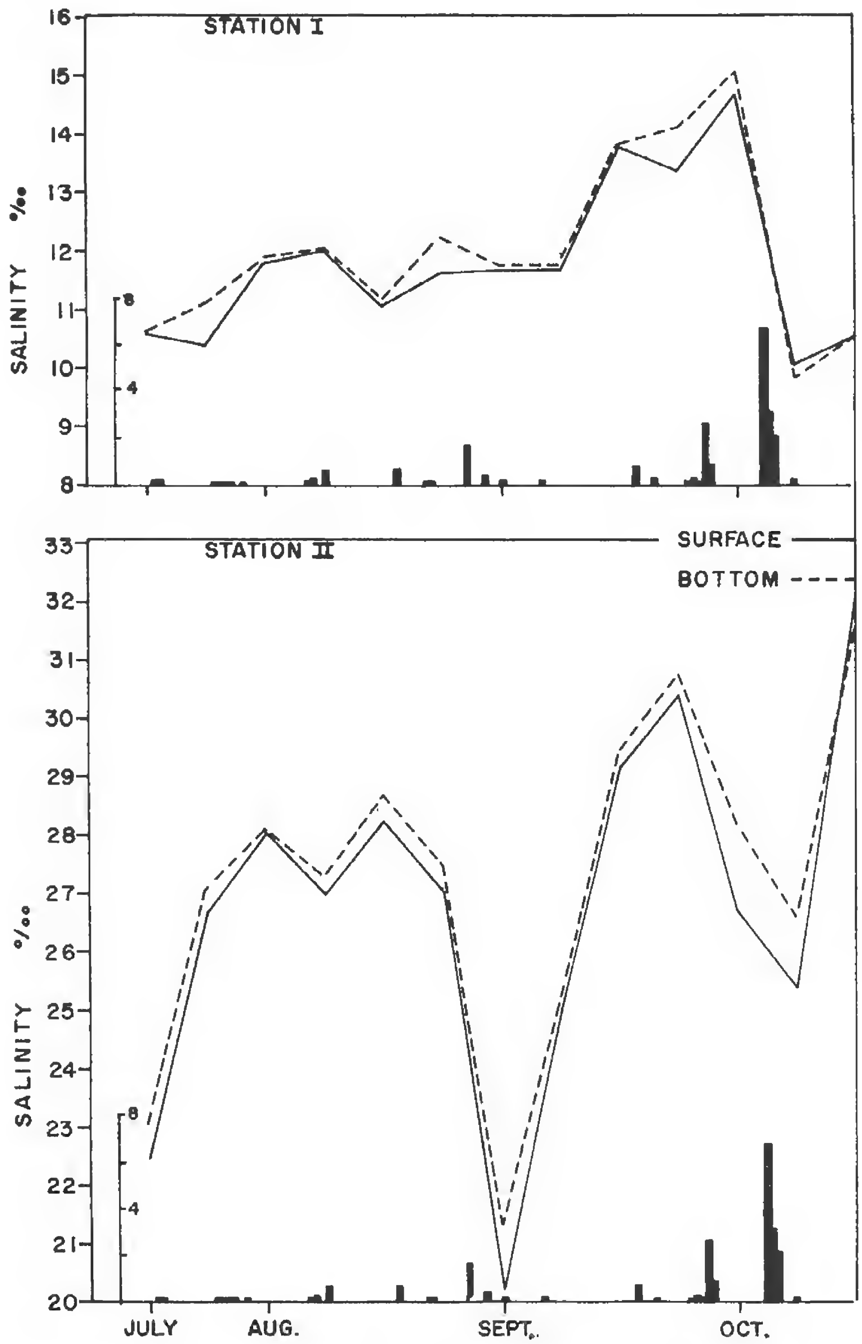


Fig. 4. Surface and bottom salinity (in o/oo) at stations I and II in the lower Pettaquamscutt River from July 11 to October 20, 1962. The vertical bars indicate rainfall in centimeters.

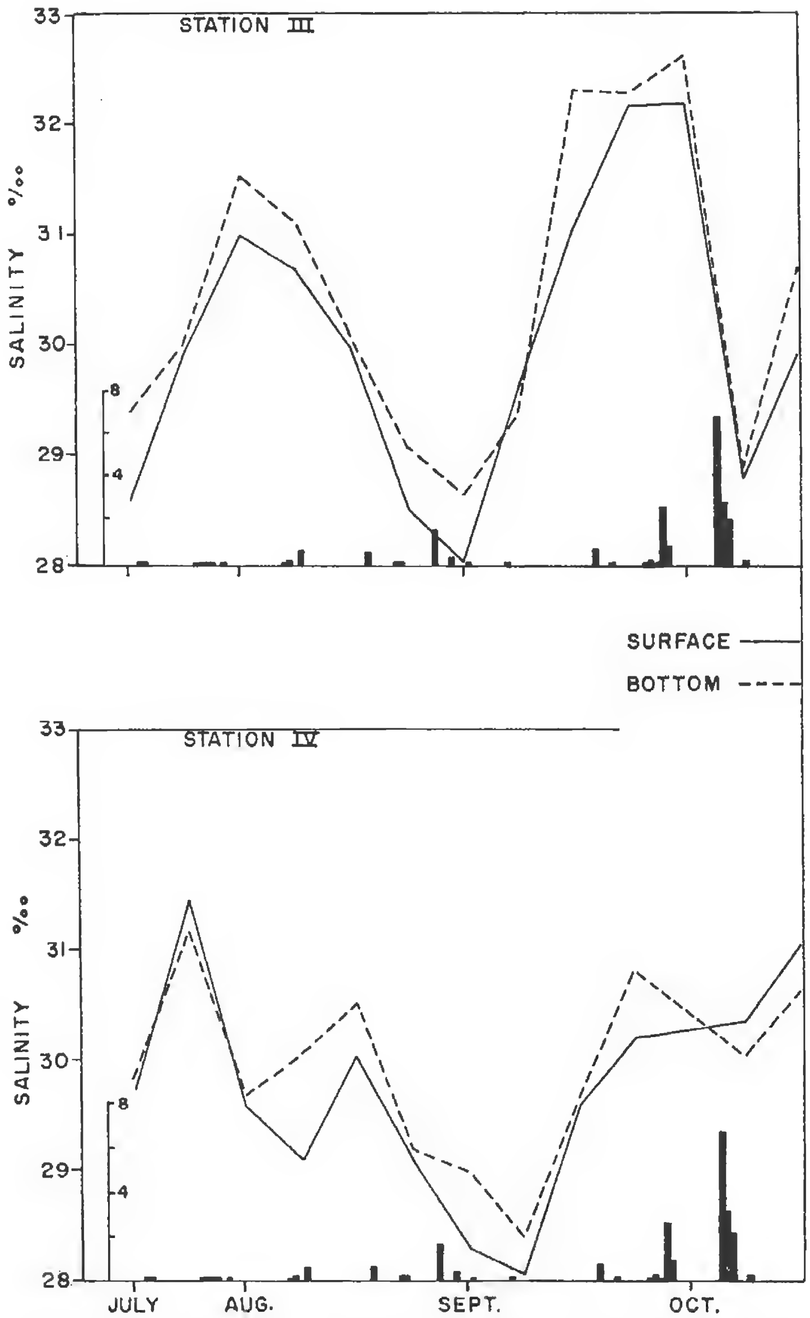


Fig. 5. Surface and bottom salinity (in o/oo) in the lower Point Judith Pond from July 11 to October 20, 1962. The vertical bars indicate rainfall in centimeters.

V. RESULTS

A. Occurrence and Abundance of Fishes

The juveniles and adults of forty-one species of fishes were collected from July 11 to October 20, 1962 in the lower Pettaquamscutt River and in the lower Point Judith Pond (Table I). Migrants of diadromous species contributed largely to the total number of species observed during the survey period. Thirty-six species occurred in the lower Pettaquamscutt River and twenty-four were recorded from the lower Point Judith Pond. Horton (1958) has reported juveniles and adults of 15 additional species of fishes from upper Pettaquamscutt River. His report includes the additional marine forms, *Hyporhamphus unifasciatus, Pollachius virens, Gadus callarias, Trinectes maculatus, Selene vomer, Seriola zonata, Alectis ciliaris, Trachinotus falcatus, T. carolinus* and *Roccus saxatilia,* and the fresh water taxa *Ameiurus nebulosus, Esox niger, Fundalus diaphnus,* and *Perca flavescens.* The species, *Lucania parva,* recorded from all four stations and *Trachinocephalus myops* collected at Bridgetown Bridge (Sta. I) have not been previously reported from Rhode Island estuaries or coastal ponds. The abundance and distribution of young fishes have been described under the appropriate headings below.

1. Total Abundance.

Total abundance represents the total number of juvenile and adult fishes captured at weekly intervals in each estuary (Fig. 7). The most significant observation in the lower Pettaquamscutt River was the appearance of the largest number of individuals in late July with pronounced pulses in August and a gradual decrease in numbers until the end of the seining operation in October (Fig. 7).

Variations in the total catches for each sampling period were influenced by the five dominant species *Menidia menidia, Fundulus heteroclitus, F. majalis, Apeltes quadracus* and *Cyprinodon variegatus.* Populations of *Brevoortia tyrannus* appeared at irregular intervals and when present, this species comprised the major taxon in the catches. Merriman (1947) and Shaw (1960) reported that *B. tyrannus* appears either in large numbers or not at all in a given habitat at any one time because of its precise schooling behavior.

In the lower Pond a single major pulse in total abundance of young fish occurred during late August followed by a fast decline in late October. Although the fluctuation in total abundance in both estuaries differed, one feature common to both areas was a rise in total abundance during the greater part of August, followed by a marked decline during the rest of the survey period.

2. Population Components.

During the warm season there was a complex influx into the estuaries of young fishes from two sources, the heads of the estuaries and the coastal and offshore waters. As a consequence it was necessary to group the fish populations into various components. The term "component" here is used to designate various types of migratory and resident groups. On the basis of information from reports of Bigelow and Schroeder (1953) and Pearcy and Richards (1962), Wheatland (1956) and Merriman and Sclar (1956)

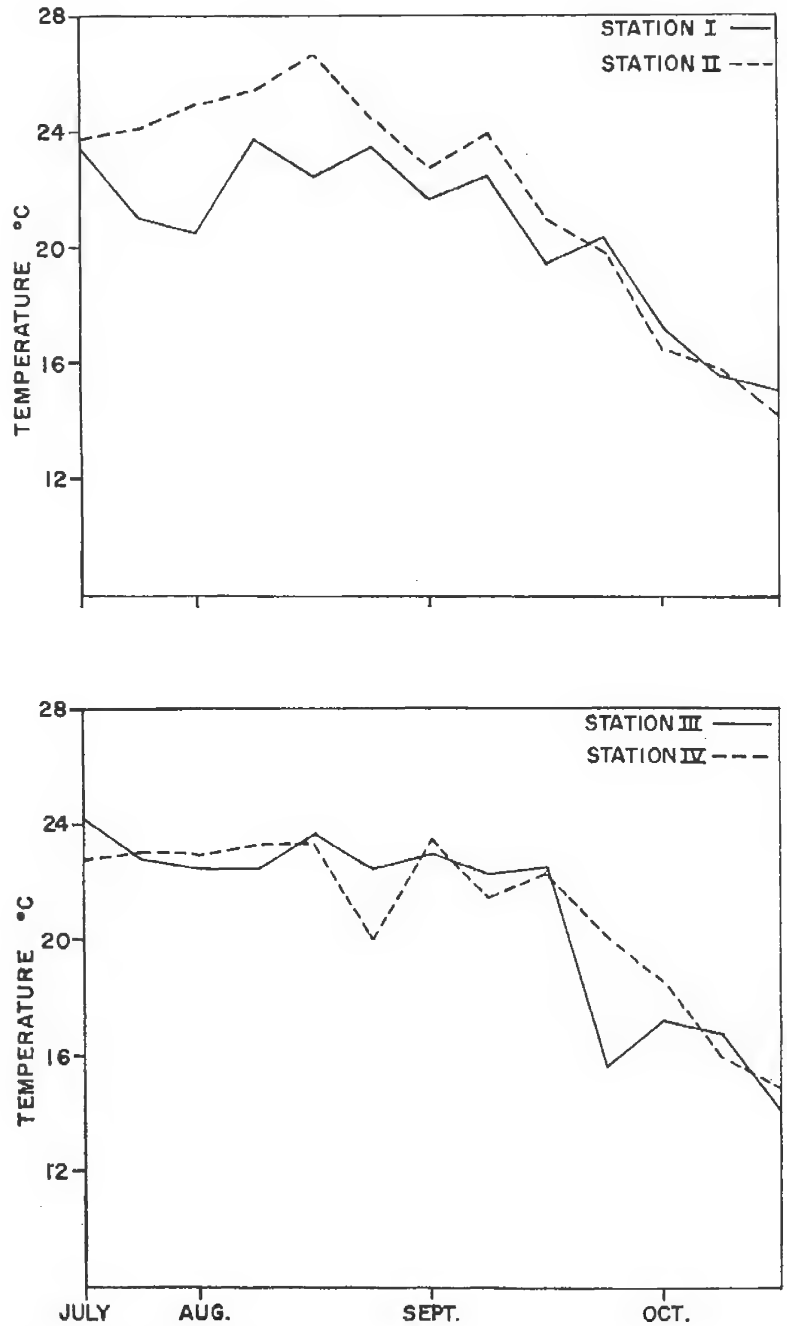


Fig. 6. Surface temperature at four seining stations in the lower Pettaquamscutt River and the lower Point Judith Pond from July 11 to October 20, 1962.

Table I. A summary of occurrence and distribution of juvenile and adult fishes collected from four seining stations in lower Pettaquamscutt River and lower Point Judith Pond, Rhode Island, during July 11 to October 20, 1962.

	Stations	Number of fishes collected	Number of recorded species	Salinity Range o/oo
I.	Bridgetown Bridge	1705	27	9.8 - 15.1
II.	Middle Bridge	6987	30	20.3 - 32.1
III.	Harbor Island	5049	23	28.05- 32.6
IV.	Galilee	5219	17	28.05- 31.5

MARINE AND BRACKISH WATER SPECIES

TOTAL ABUNDANCE OF EACH SPECIES

RESIDENT SPECIES	STATIONS I	II	III	IV
1. *Cyprinodon variegatus* (Lacépède) Sheepshead minnow	197	700	41	426
2. *Fundulus heteroclitus* (Linnaeus) Common mummichog	235	676	996	1468
3. *Fundulus majalis* (Walbaum) Striped mummichog	71	378	491	1315
4. *Lucania parva* (Baird and Girard) Rain-water fish	1	2	1	2
5. *Microgadus tomcod* (Walbaum) Tomcod	—	2	—	—
6. *Apeltes quadracus* (Mitchill) Four-spined stickleback	23	2045	101	507
7. *Gasterosteus aculeatus* (Linnaeus) Three-spined stickleback	6	129	519	49
8. *Pungitius pungitius* (Linnaeus) Nine-spined stickleback	—	7	—	—
9. *Syngnathus fuscus* (Storer) Pipefish	31	26	13	5
10. *Roccus americanus* (Gmelin) White perch	75	—	—	—
11. *Tautoga onitis* (Linnaeus) Tautog	—	24	59	6
12. *Tautogolabrus adspersus* (Walbaum) Cunner	—	16	36	29
13. *Gobiosoma bosci* (Lacépède) Naked Goby	1	—	—	—
14. *Prionotus evolans* (Linnaeus) Striped sea robin	1	3	—	—
15. *Myxocephalus aeneus* (Mitchill) Grubby sculpin	—	2	1	3
16. *Menidia menidia* (Linnaeus) Silversides	718	2377	1586	1155
17. *Pseudopleuronectes* americanus (Walbaum) Winter flounder	17	379	3	103
18. *Opsanus tau* (Linnaeus) Toadfish	1	7	1	—

MIGRANT SPECIES	STATIONS I	II	III	IV
1. *Brevoortia tyrannus* (Latrobe) Menhaden	162	66	922	131
2. *Clupea harengus* (Linnaeus) Sea herring	4	—	—	—
3. *Anchoa mitchilli* (Cuvier et Valenciennes) Anchovy	1	2	177	5
4. *Osmerus mordax* (Mitchill) Smelt	—	—	84	5
5. *Trachinocephalus myops* (Forster) Snake fish	1	—	—	—
6. *Strongylura marina* (Walbaum) Atlantic needlefish	—	2	—	—
7. *Urophycis chuss* (Walbaum) Squirrel hake?	—	1	—	—
8. *Lutjanus griseus* (Linnaeus) Grey Snapper	3	—	1	—
9. *Pristigenys alta* (Gill) Short big eye	1	3	—	—
10. *Pomatomus saltatrix* (Linnaeus) Bluefish	—	—	1	—
11. *Caranx crysos* (Mitchill) Hardtail	58	—	—	—
12. *Stenotomus versicolor* (Mitchill) Scup	—	—	6	—
13. *Chaetodon ocellatus* (Bloch) Butterfly fish	—	—	4	—
14. *Sphyraena borealis* (DeKay) Northern barracuda	—	—	1	—
15. *Mugil cephalus* (Linnaeus) Mullet	2	12	—	1
16. *Paralichthys dentatus* (Linnaeus) Summer flounder	1	1	—	—
17. *Alutera schoepfii* (Walbaum) Unicornfish	—	1	1	—
18. *Monocanthus hispidus* (Linnaeus) Filefish	2	36	4	9
19. *Sphaeroides maculatus* (Bloch and Schneider) Puffer	2	5	—	—
ANADROMOUS SPECIES:				
1. *Alosa aestivalis* (Mitchill) Blueback	11	16	—	—
2. *Alosa pseudoharengus* (Wilson) Alewife	78	68	—	—
CATADROMOUS SPECIES:				
1. *Anguilla rostrata* (LeSueur) American eel	2	3	—	—
FRESH WATER SPECIES:				
1. *Micropterus salmoides* (Lacépède) Largemouth bass	—	1	—	—

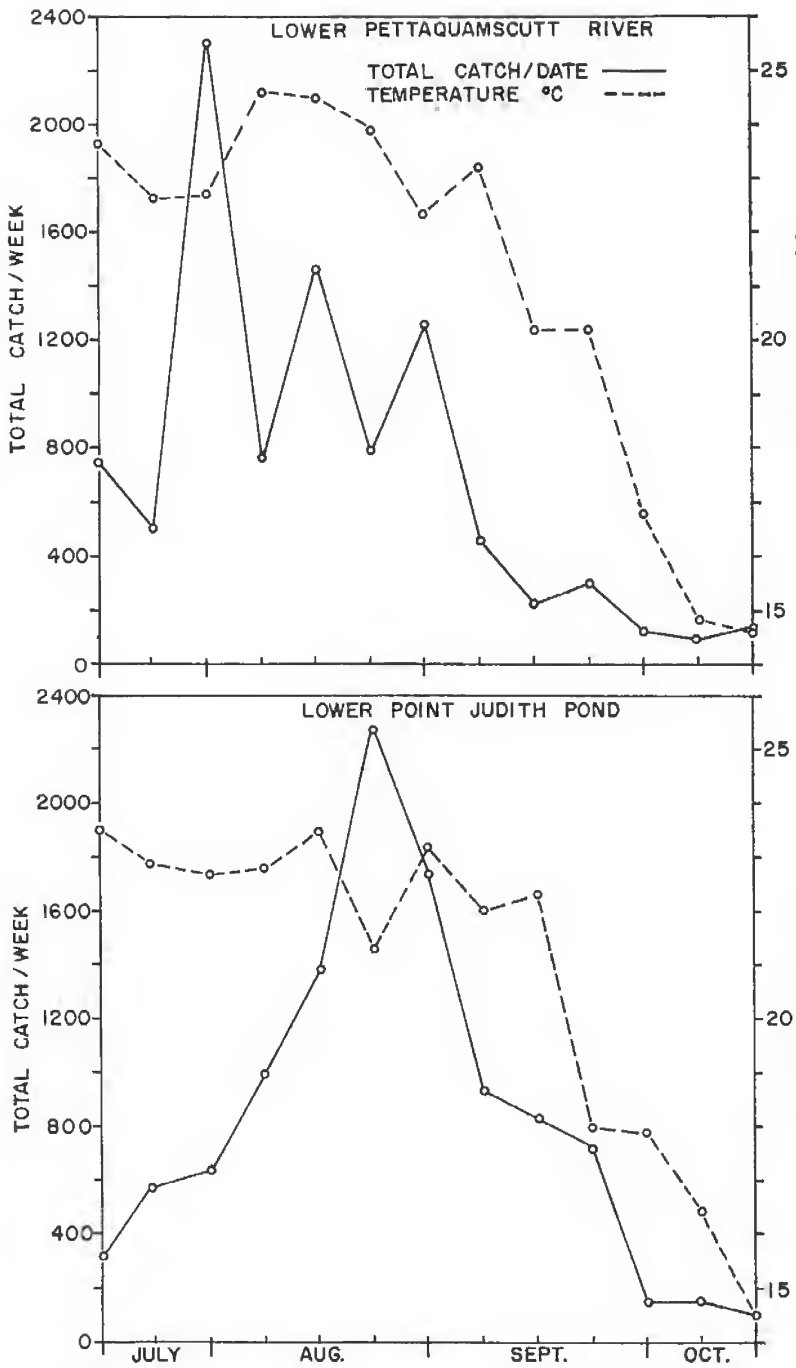


Fig. 7 Variations in total weekly catches and temperature from July 11 to October 20, 1962.

various species were grouped into the following components (Table I): 1) Resident species, species that spend a great part of their life in local estuarine environments; 2) seasonal migrants, including offshore and inshore coastal waters, immature forms as well as southern species from the lower latitudes; 3) immature fishes of anadromous species; 4) immature catadromous forms, and 5) fresh water fish.

Although there were more migrant species of fishes recorded during the survey than resident forms, the number of resident species occurring in both estuaries during the survey period was always significantly larger. In the lower Pettaquamscutt River there was a rapid increase in the number of resident species during the first month (Fig. 8). By contrast, migrant species maintained a steady population level after the first rise in the number of species. A peak in the abundance of both endemic and migrant species populations occurred in the early part of September. The highest number of resident species populations observed at any one time during the survey period was 13 (Fig. 8). However only seven migrant species were recorded during the highest pulse in September.

Only 10 migrant species were recorded from the lower pond in comparison with 17 collected from the lower river. A rapid increase in number of species in the catches was noted from July 18 to August 14. Two pulses occurred on September 14 and October 4, followed by a sharp decrease in October (Fig. 8).

3. Relative Abundance.

The analysis of relative abundance of all species of fishes, indicates the relative ranks for each major species contributing to the bulk of populations of fishes from all the seining stations (Table II). The relative abundance and rank data of three selected species indicate the ranks with respect to major species at weekly intervals (Figs. 9-11 and Table II). A common feature of these data from all collections was the presence of a few dominant species represented by a large number of individuals and a large number of subordinate species represented by few individuals.

The major species in order of abundance were *Menidia menidia, Fundulus heteroclitus, F. majalis, Apeltes, quadracus, Cyprinodon variegatus, Brevoortia tyrannus* and *Gasterosteus aculeatus,* (Table II). Other commonly occurring species were *Pseudopleuronectes americanus, Tautoga onitis, Tautogolabrus adspersus, Syngnathus fuscus,* and *Alosa pseudoharengus.* The species *Osmerus mordax* and *Anchoa mitchilli* comprised the major species on certain dates (date on file). The taxa, *Roccus americanus* and *Caranx crysos,* were common only at the landward station in the lower Pettaquamscutt River and appeared consistently.

Among the selected species, *M. menidia* was usually first in order of abundance and a major species in most of the catches in both estuaries at all stations. The fluctuations in relative abundance were more pronounced at both seaward stations (Figs. 2 and 9). Though the number of individuals in the catches was fewer at Station I (Figs. 1 and 9), these fish maintained comparatively steady population level in both estuaries at both landward stations. An apparent existing fluctuation in catches may be due to the schooling behavior of this species as reported by Shaw (1960).

SUMMARY

1. An extensive sampling project in Mississippi Sound and adjacent waters was carried out during the two years between November 1962 and the end of October 1964.

2. Postlarval pink shrimp were reported from this area for the first time.

3. The salinity regime in the years was very different.

4. From a total of 31 stations established, four were selected as being suitable for use in long term studies of postlarval abundance.

5. Indices of abundance developed from the catch of postlarvae at the selected stations predicted the 1964 catch of both white and brown shrimp within ten per cent.

6. Determination of the relative abundance of postlarval penaeid shrimp by season and area in Mississippi Sound and adjacent waters seems to be feasible, but reliability of the indices has not been fully established. Refinement of the indices and several more years experience will be required to refine the predictions.

REFERENCES

Baxter, Kenneth N.
1962. Abundance of postlarval shrimp — One index of future shrimping success. Proceedings of the Gulf and Carribean Fisheries Institute, Fifteenth Annual Session, November, 1962, pp 79-87.

Collier, Albert and Joel W. Hedgpeth
1950. An introduction to the hydrography of tidal water of Texas. Publications of the Institute of Marine Science, University of Texas, vol. 1, no. 2, pp. 125-179.

Lindner, Milton J. and William W. Anderson
1956. Growth, migrations, spawning and size distribution of shrimp *Penaeus setiferus.* United States Fish and Wildlife Service, Fishery Bulletin 106, vol. 56, pp. 553-645.

Phleger, F. B.
1954. Ecology of Foraminifera and Associated Micro-organisms from Mississippi Sound and Environs, Amer. Assoc. Pet. Geol. Bull., Vol. 38, no. 4, pp. 584-647.

Priddy, R. Crisler, M., Sebren, P., Powell, D., and Burford, H.
1955. Sediments of Mississippi Sound and Inshore Water. Mississippi State Geological Survey, University of Mississippi, Bulletin 82, 53 pp.

Renfro, William C.
1962. Small beam net for sampling postlarval shrimp. *In:* Galveston Biological Laboratory — Fishery research for the year ending June 30, 1962. United States Fish and Wildlife Service, Circular 161, pp. 86-87.

Table II. Relative abundance of the major species in order of their ranks with respect to all species collected from July 11 to October 20, 1962 from the lower Pettaquamscutt River and the lower Point Judith Pond, R. I.

		Lower Pettaquamscutt River				Lower Point Judith Pond			
		Station I		Station II		Station III		Station IV	
	Species	Relative %	Rank	Relative %	Rank	Relative %	Rank	Relative %	Rank
1.	*Menidia menidia*	42.1	1	30.4	1	31.5	1	22	3
2.	*Fundulus heteroclitus*	13.8	2	9.7	4	18.9	2	28.2	1
3.	*Fundulus majalis*	4.16	7	5.4	6	9.7	5	25.2	2
4.	*Apeltes quadracus*	1.35	10	28.8	2	2	7	9.4	4
5.	*Cyprinodon variegatus*	11.55	3	10	3	.81	10	8.1	5
6.	*Brevoortia tyrannus*	9.45	4	.94	9	18	3	2.5	6
7.	*Gasterosteus aculeatus*	.35	13	1.85	7	10.4	4	.95	8
8.	*Pseudopleuronectes americanus*	.99	11	5.44	5	.05	15	1.95	7
9.	*Alosa pseudoharengus*	4.6	5	.97	8	—	—	—	—
10.	*Sygnathus fuscus*	1.72	9	.37	11	.2	12	.09	12
11.	*Tautoga onitis*	—	—	.34	12	1.17	9	.12	11
12.	*Tautogolabrus adspersus*	—	—	.23	13	.7	11	.55	9
13.	*Roccus americanus*	4.4	6	—	—	—	—	—	—
14.	*Caranx crysos*	3.4	8	—	—	—	—	—	—
15.	*Monocanthus hispidus*	.12	16	.51	10	.07	14	.17	10

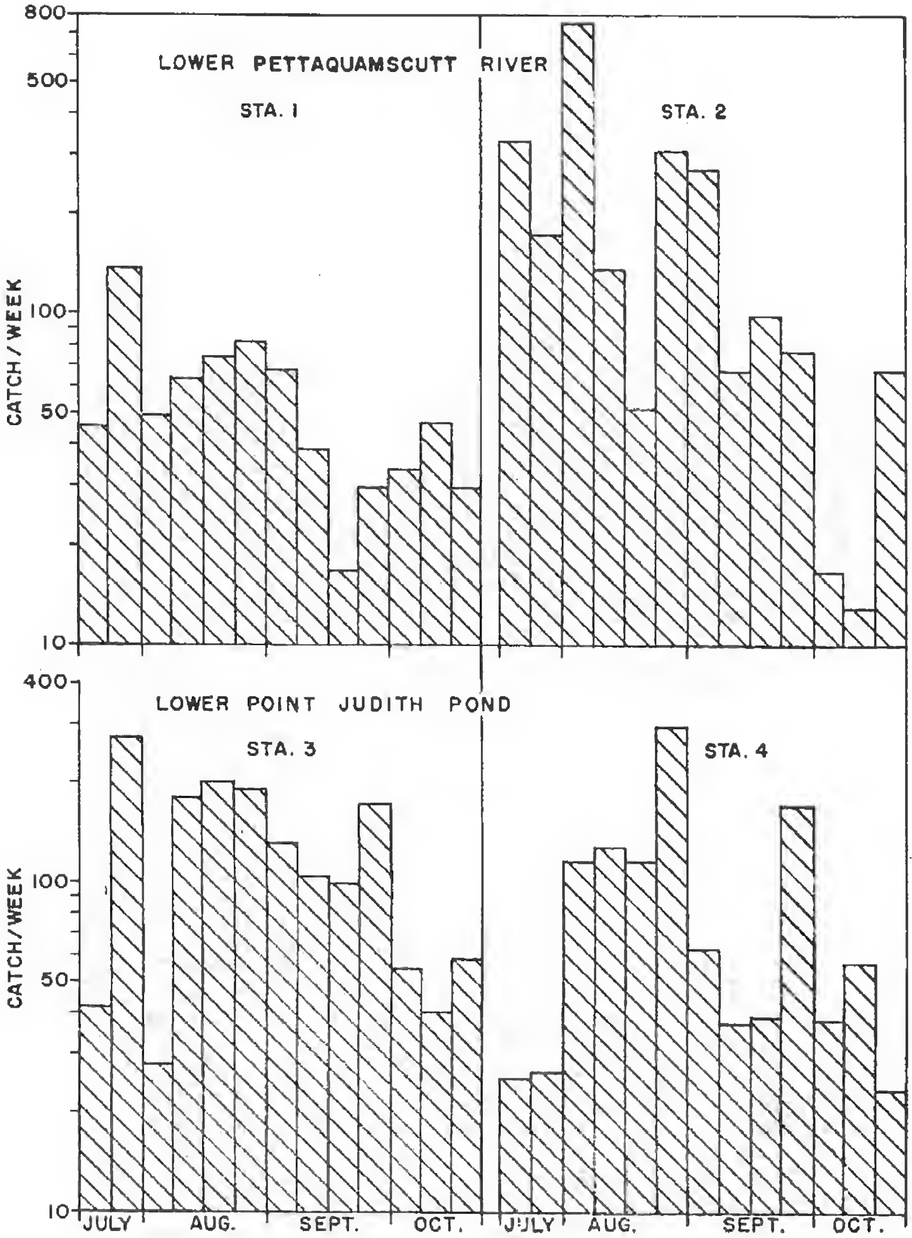


Fig. 9. Variations in weekly catches of *Menidia menidia* (Juvenile and adult) from July 11 to October 20, 1962.

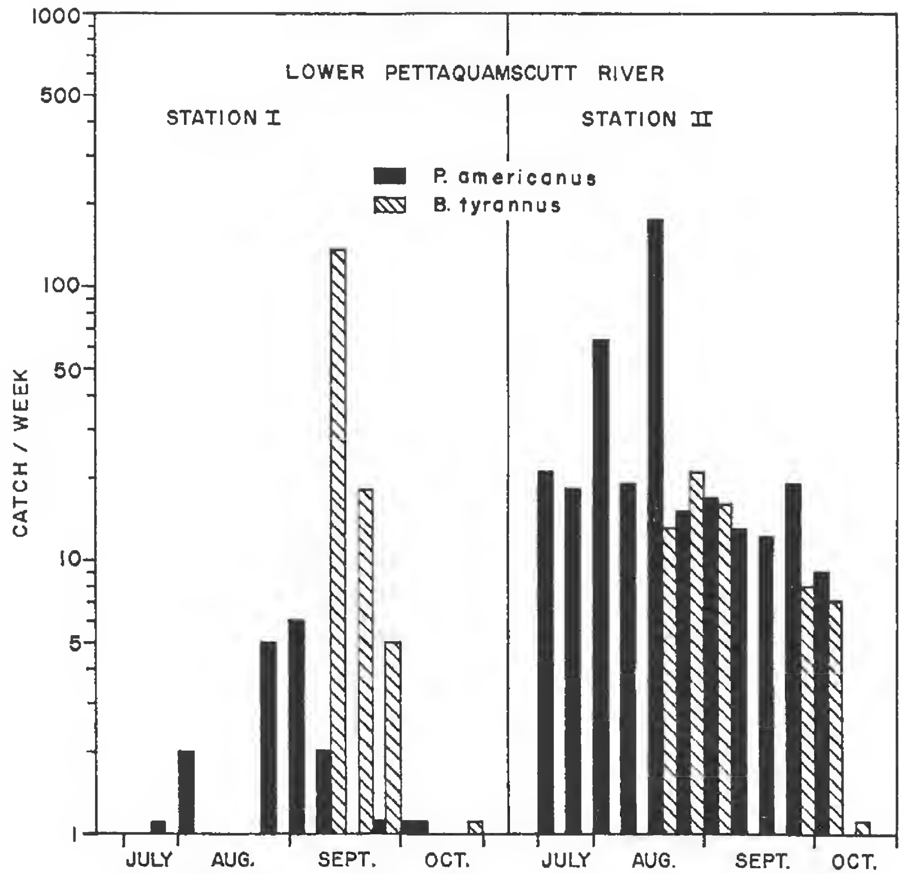


Fig. 10. Variations in weekly catches of juvenile *Pseudopleuronectes americanus* and *Brevoortia tyrannus* from July 11 to October 20, 1962 in lower Pettaquamscutt River.

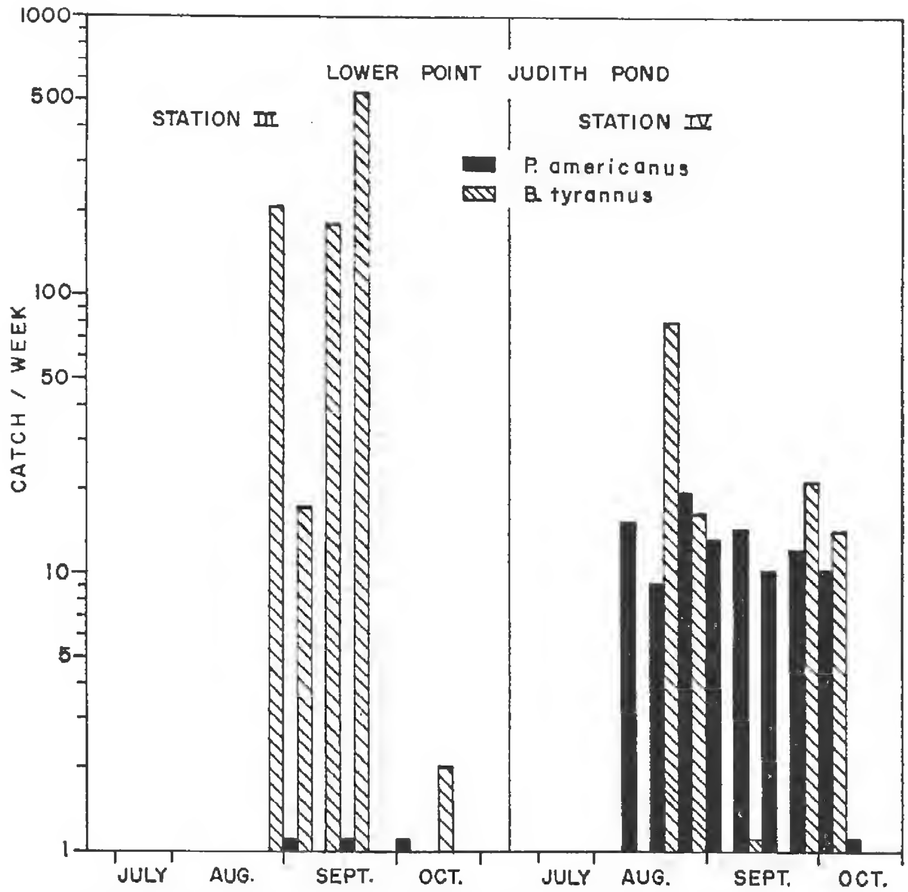


Fig. 11. Variations in weekly catches of juvenile *Pseudopleuronectes americanus* and *Brevoortia tyrannus* from July 11 to October 20, 1962, in lower Point Judith Pond.

The taxon, *Brevoortia tyrannus* ranked sixth in order of abundance (Table II), but the appearance of this species was extremely variable from week to week. Its greatest abundance was at the more landward station at Harbor Island in the lower Pond for most of September (Figs. 2, 10 and 11), and at the seaward station during the later half of August and early October. These fish were collected in significant numbers during mid-September at the landward station in the lower Pettaquamscutt River (Fig. 1) and at the seaward station in mid-August and early September.

Pseudopleuronectes americanus ranked eighth in abundance among the total species recorded. This taxon was relatively common at the seaward stations in both estuaries (Figs. 1, 2, 10 and 11). These fish were not numerous at the upper stations of either estuary. Only three second-year class individuals appeared at Harbor Island. The low efficiency of the "shore seine" on a rocky irregular bottom may have affected the catch record from this station.

4. Horizontal Distribution.

Disparity in distributional patterns of young fish was demonstrated by various migrant and resident species along the north-south axis of the study areas in the two estuaries. Juvenile *Brevoortia tyrannus* tended to move seaward as they grew as the season progressed. This taxon was particularly abundant at Harbor Island (Sta. III, Fig. 2) from August 28 to September 14. The size of the young fish in the first catch from this station varied between 29 and 44 mm. The mean length of the individuals in the last sample taken on September 14 was 52 mm. By early October these fish had grown to a mean size of 58 mm, but by this time they occupied the seaward station in the lower pond. McHugh *et al.* (1959) reported that populations of *B. tyrannus* move towards the sea as they grow and that consequently the mean size is greater at the seaward end of estuaries. A similar pattern of ditsribution was apparent in the lower Pettaquamscutt River. A greater number of individuals appeared at the landward station in August (Figs. 1 and 10). But the larger sized fish collected at two consecutive occasions during October were mainly from the seaward station (Figs. 1, 10 and 14).

Two anadromous species, *Alosa pseudoharengus* and *A. aestivalis,* occurred only in the river estuary (Table I). These fishes appear to populate the river from July to late September as immature emigrants. It would be expected that these species behave as other anadromous species wherein the breeding populations enter brackish or fresh water environments from the sea during spawning season, the young emigrants moving out from the estuaries as they grow. The lower Point Judith Pond, which covers more than three-fourths of the entire area, is subjected to near-seawater salinity (Figs. 4 and 5). This N/neritic condition (Fig. 3) should be adverse for spawning activities by anadromous species. Since no young fish of the two species appeared in catches throughout the survey period these observations indicate that the pond is probably not serving as a spawning area for these fishes.

The taxon, *Pseudopleuronectes americanus,* usually spawns in winter at the heads of estuaries (Bigelow and Schroeder, 1953; Perlmutter, 1939). Pearcy (1952) found that young fish move down stream as they grow. Only three individuals of the first year class appeared at Bridgetown Bridge (Sta. I, Fig. 1). A great number of the same year class fish were captured from Middle Bridge (Sta. II, Fig. 1). Fourteen second year class fish

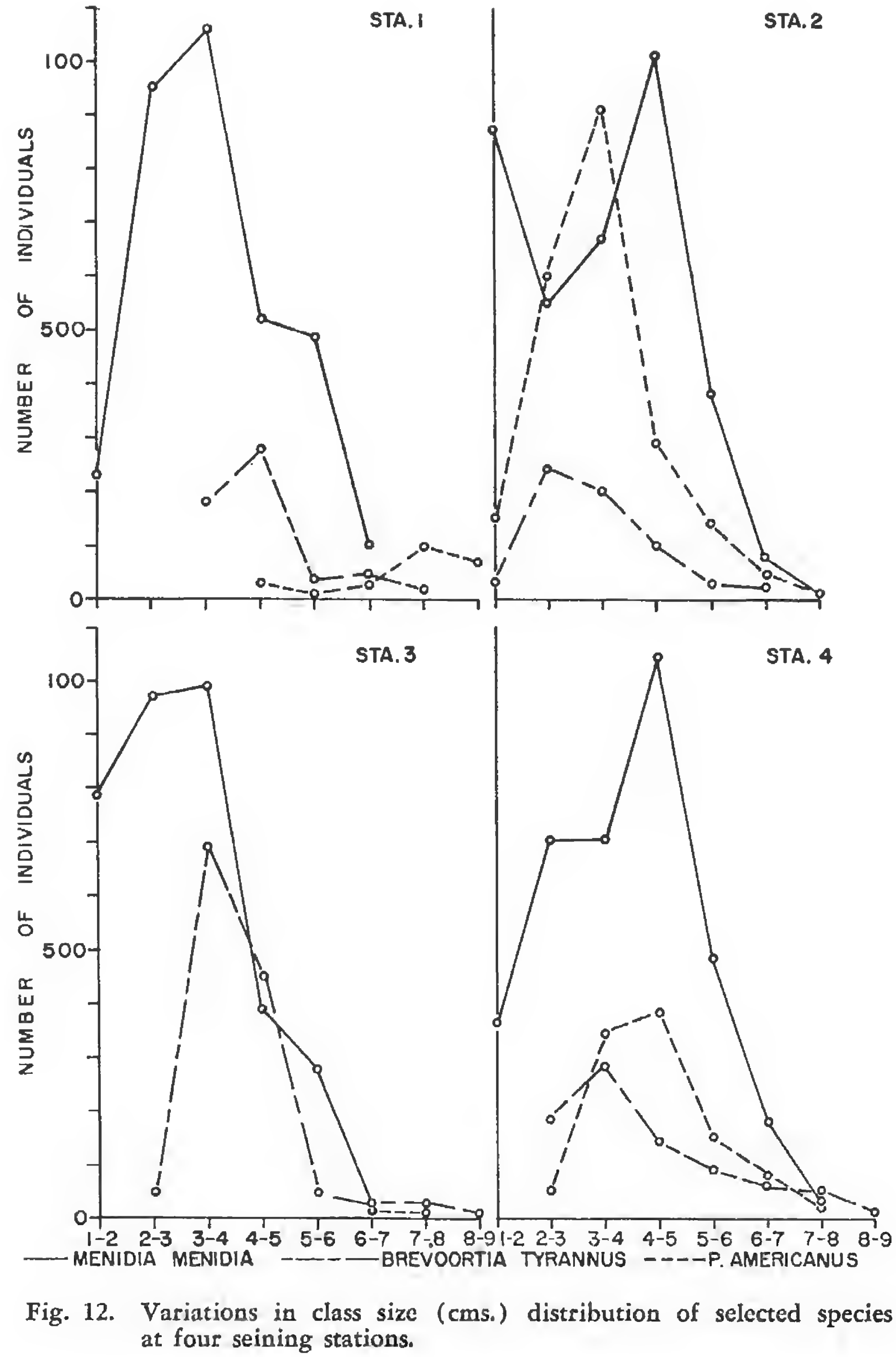


Fig. 12. Variations in class size (cms.) distribution of selected species at four seining stations.

were caught only at the landward station throughout the survey period (Figs. 1 and 12). These observations reveal that probably juvenile fish of the first year class occupy seaward stations by late summer. Second-year or older classes of fish either populate the more inland portions of estuaries (Figs. 1, 2 and 12), or wander randomly, since larger fish rarely were seen at the seaward stations in either estuary.

In lower Point Judith Pond only three specimens of *P. americanus* of the second-year class were caught at Harbor Island during the entire study period. The larger samples of this species were collected at the seaward station (Sta. IV, Fig. 2).

The species *Menidia menidia* which appeared consistently at all four stations in both the estuaries in considerable abundance, had a greater abundance of size group 40-50 mm at the more seaward stations in the two estuaries. The size group 30-40 mm was more common at the landward stations (Figs. 1, 2 and 12). Only two fish, possibly belonging to third-year class (120 mm) were collected from the landward station in the lower Point Judith Pond.

The taxa *Caranx crysos, Clupea harengus, Roccus americanus* and *Gobiosoma bosci* ocurred only at Station I (Table II, Fig. 1). A few species represented by *Strongylura marina, Microgadus tomcod, Urophycis chuss* and *Micropterus salmoides* were taken only from Middle Bridge area (Sta. II, Fig. 1), and in very small numbers. The catches of *Sphyraena borealis, Pomatomus saltatrix* and *Chastodon ocellatus* were exclusively recorded from Harbor Island. The species *Tautoga onitis* and *Tautogolabrus adspersus* never appeared at Bridgetown Bridge Station. These fishes were common and frequently were found at Middle Bridge Station and Harbor Island, exhibiting mimicking behavior in massive beds of *Zostera marina* and various types of algae (Table II, Figs. 1 and 2).

B. GROWTH

Growth is a measure of production and an important means of studying ecological variations in various types of environments. The growth study of selected species of fishes of zero-year class includes the rate of growth-in-length in the two estuarine systems under study. The average length of each sample used in graphic analysis was also employed to determine growth rates. The growth of each species has been dealt with separately.

1. *Pseudopleuronectes americanus.*

While controversy exists on the exact spawning period of this species, Pearcy (1952), Perlmutter (1939) and Bigelow and Schroeder (1953) concluded that *P. americanus* is essentially a winter spawner.

The juvenile winter flounder, consisting of 11 samples and totaling 382 individuals taken from the lower Pettaquamscutt River, provided average lengths used in comparing series of samples in computing rates of growth. The first sample collected on July 11 included juvenile fish with a mean length of 26 mm, and a size range between 15 and 44 mm. These fish were probably four to six months old at that time (Bigelow and Schroeder, 1953). The first two samples, taken at an interval of one week in July (Fig. 13) showed 50% overlap of black bars. Such a degree of overlap indicates little significance in the differences between samples and a low reliance on growth increments. This situation appears when

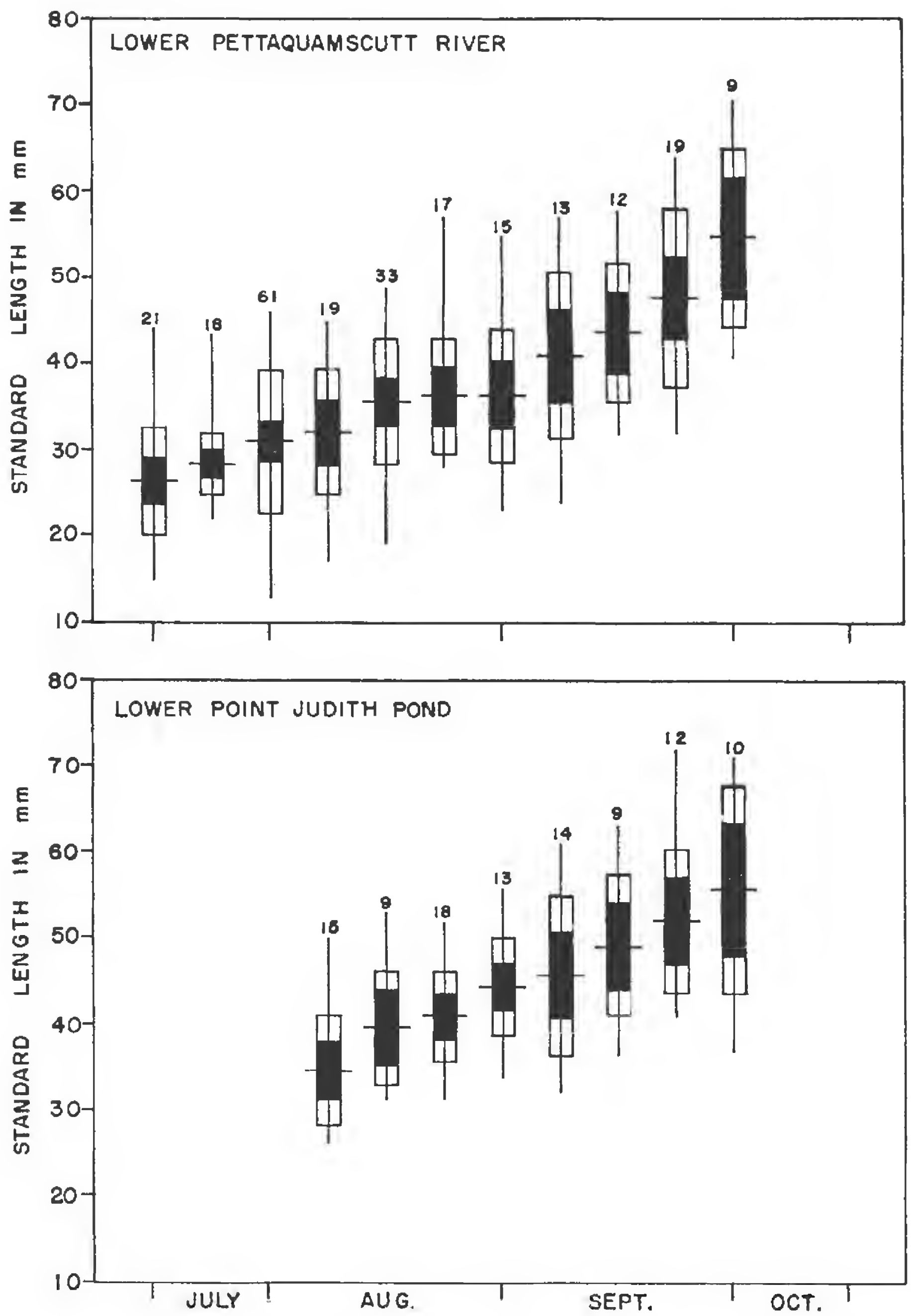


Fig. 13. Average growth of juvenile *Pseudopleauronectes americanus* collected July 11 to October 20, 1962.

LEGEND FOR FIGURE 13

The vertical lines in the histograms (Figs. 13-16) indicate size range of standard lengths in each sample. The horizontal lines are means. The black bar on either side of the mean represents two standard errors of mean ($2\sigma M$), and the black bar and white bar combined on either side of the mean is the standard deviation (σ). The standard errors express a measure of reliability, while standard deviation is a measure of dispersion. For a detailed description see Hubbs and Perlmutter (1942) and Hubbs and Hubbs (1953).

The sample sizes, given at the top of the vertical lines representing 30 or more individuals, are sub-samples from larger collections. The rest of the samples are actual sample sizes.

---

samples are compared at week intervals. But given an interval of two weeks or a month, the samples in almost all cases show less than one-third overlap. Significant differences do appear between samples and a reliance on growth increments can then be demonstrated. The samples collected during the latter half of August showed significant differences between samples.

The size of the fish when first caught in early August in the Pond estuary (Sta. IV, Fig. 2) ranged between 26 mm to 50 mm, with a mean length of 35 mm. The increase in the average length of the juvenile fish from early August to early October (Fig. 13) was between 35 and 56 mm with a growth rate of 10.5 mm per month. Though these results compare favorably with other studies (Pearcy, 1962) pertaining to this species, the single method of sampling and the small sample sizes do not lend thorough examination of differences in variations in growth between the study areas in the two estuaries. Seining operations coupled with intensive otter-trawling would probably manifest a more exact picture of growth and variations in the two environments.

2. *Brevoortia tyrannus.*

Since *B. tyrannus* has a split spawning season, it is important to know the approximate age at which the fish first appeared in catches. Kuntz and Radcliffe (1917) reported that *B. tyrannus* spawns in summer in Woods Hole and in late fall in Chesapeake Bay. Wheatland (1956) observed two peaks in egg production in this species in Long Island Sound, one in June and the other in September. Herman (1958) found that this fish spawns in Narragansett Bay from May to August and again in October. Age estimates for this species, according to scale studies by Hile (1948) and others, show all fish captured were fish-of-the-year and were approximately three to four months old when they first appeared in catches (Fig. 14). In the present study the sporadic appearance of *B. tyrannus*, a schooling species, dictated the necessity of pooling the data from both lower and upper stations in each estuary. The limitations of this decision are fully recognized by the writer.

The study of the growth rate of *B. tyrannus* in the lower Point Judith Pond was based on data from 1053 individuals from seven samples. The first sample collected on August 14 consisted of 79 fish, with a size range between 27 and 36 mm and a mean length of 33 mm. The two samples taken on August 14 and August 21, displayed significant difference, hence mean values of these samples are reliable (Fig. 14). The late

August and early September data had a marked overlap (Fig. 14). The resulting low reliance on mean length measurements is probably due to the small sample sizes. The samples collected from September 14 to October 4 showed much wider variations in the sizes of the individual fish and displayed marked overlap of black bars, with respect to weekly intervals. But in two of these samples the standard deviation is more than twice the two standard errors on either side of the means, signifying that valid differences exist between the two samples (Hubbs and Perlmutter, 1942).

The graphical analysis demonstrated two distinct groups among all the samples. As this species schools precisely according to size (McHugh, 1959), it seemed that fish appearing after September 4 represented various populations. The mean standard length of the first group collected from August 14 to September 4 increased from 31 to 38 mm, with a growth increment of 7 mm per month (Fig. 18). The first sample of the second group taken on September 14 was caught only at the landward station while the rest of the samples were taken from seaward stations (Figs. 1, 2 and 11). The increase in average length observed was from 52 to 58 mm or an increase of 6 mm in three weeks (Fig.18). McHugh *et al.* (1959) contended that schools of *B. tyrannus* of precise size groups form a distinct size gradient from one end of the estuary to the other. McHugh insisted that a single rate of growth for a given age group of such a widely ranging species occupying an estuary is not tenable. The presence of two distinct groups and catches of larger fish mainly at seaward stations during late September and October (Figs. 10-12) point to analogy with McHugh's findings. However the growth data for this species compares favorably with studies of Warfel and Merriman (1944) and McHugh *et al.* (1959)

The average lengths of seven samples consisting of 228 individuals collected from the lower Pettaquamscutt River, were used for growth study. Two distinct groups of zero-year class fish were present in this estuarine system as well (Fig. 14). The significant differences existed between samples collected from mid-August to early September. The black bars of the samples taken during the rest of September demonstrated marked overlapping thus negating the possibility of significance in differences (Fig. 14).

The mean length for all samples collected from mid-August to early September showed an increase from 25 to 43 mm (Fig. 17). This increase of 18 mm per month for the population in the lower Pettaquamscutt River estuary was more than twice the growth rate estimated for young fish collected during the same period from the lower Point Judith Pond (Figs. 17 and 18). However the growth was insignificant in the rest of the three samples which were composed of individuals of diverse size ranges. The sporadic appearance of this schooling species was another factor which created irregularity in catches and hence made it difficult to trace the exact picture of growth (McHugh *et al.,* ibid).

3. *Menidia menidia.*

There is no definite growth study of juvenile or adult *Menidia menidia.* The wide range of sizes present in all samples during the present survey created a problem in the attempt to distinguish the zero-plus group. Merriman (1947) and Bigelow and Schroeder (1953) found that sizes ranging from fry of 2.5 cm (1 inch) long to adult sizes are present during the summer months. Williams (1960) and Shaw (1960) consider the

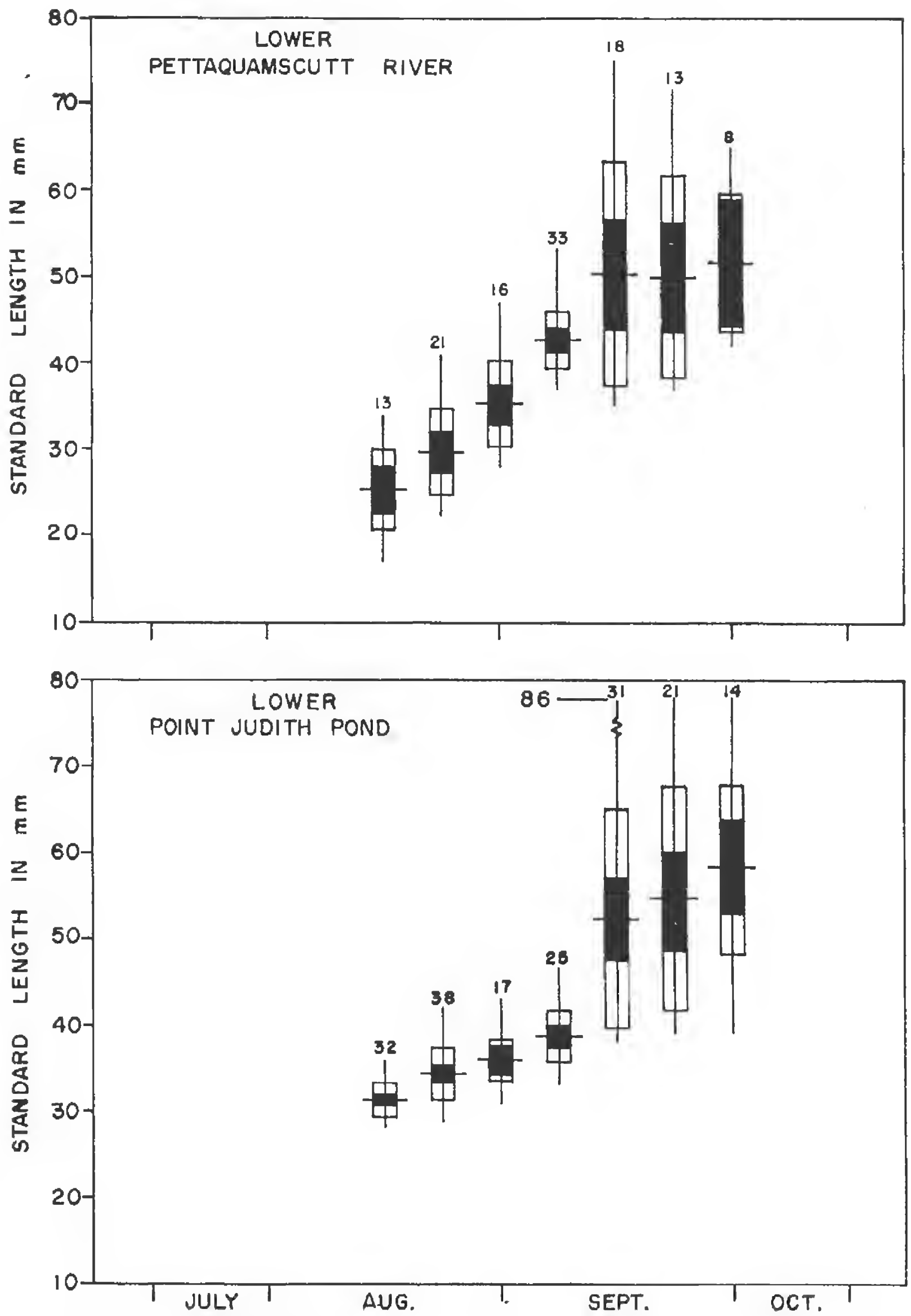


Fig. 14. Average growth of juvenile *Brevoortia tyrannus* collected from July 11 to October 20, 1962. Method of presentation is the same as given in Fig. 13.

minimum size of an adult fish to be 50 mm. Spawning is reported to occur from May through July (Herman, 1958) in New England waters. From July to early September juvenile fish could be separated from other age groups, because of a marked distinction in sizes. For the remaining period fast growing juvenile and slow growing adult fish occurred in a complex admixture of sizes from which the zero-plus group could not be sorted out with certainty. It is possible that the small sized fish may rapidly disappear from the estuaries, perhaps retreating to deep water in the cooler part of the season (Hildebrand and Schroeder, 1928).

Thirteen samples from Bridgetown Bridge (Sta. I, Fig. 1) consisting of over 500 fish provided data for comparison. The samples collected from July 11 to September 3 demonstrated significant differences when collected at semi-monthly or monthly intervals. The marked overlapping in samples taken from late August to early September seemed due to influx of larger numbers of small size individuals which also tended to diminish the mean growth in these samples (Fig. 15). The samples collected from September 9 to October 20 contained both juvenile and adult fish. Although significant differences were observed in these collections, the relative composition of the samples including juvenile and adult fish of uncertain age groups invalidated the mean values given.

The average length of juvenile fish rapidly increased from July 11 to September 3 attaining a size range from 19 to 35 mm. The growth increments were insignificant for three weeks from August 16 to September 3, due to an inclusion of a larger number of smaller sized individuals (data on file). The growth rate of the juvenile fish was 8 mm per month (Fig. 17). There is uncertainty in establishing a growth rate for fish taken from September 9 to October 20, because of the admixture of juvenile and adult fish of various sizes.

From 13 samples consisting of over 1500 fish from Middle Bridge (Sta. II), juvenile fish could confidently be separated out from the first eight samples. These samples taken from July 11 to August 2 demonstrated significant differences. The increase in average growth of young fish in these samples (13 to 27 mm) suggests that the growth rate is more rapid during the early juvenile phase (Figs. 15 and 17). Samples taken during early August show an overlap in black bars, probably due to the small sample sizes. The insignificant differences in collections from August 16 to September 3 is apparently due to the appearance of schools of similar sized individuals in the catches. The overall increase observed in growth from July 11 to September 3 was from 12 mm to 40 mm, or 14 mm per month (Fig. 17). Although significant differences between the samples are apparent, the problem of uncertain age group composition negated the possibility of estimating exact rates of growth for this species after September 3.

Although there were variations in average growth, the samples from the lower pond demonstrated a similar pattern of growth when compared to the catches from the lower river. The collections made from the Harbor Island (Sta. III) indicated significant differences at semi-monthly intervals (Fig. 16). The samples taken from September 4 to September 22 and October 4 to October 20, included a higher number of smaller size young fish in September samples and a higher number of larger size fish in October collections. The significance of differences between these samples

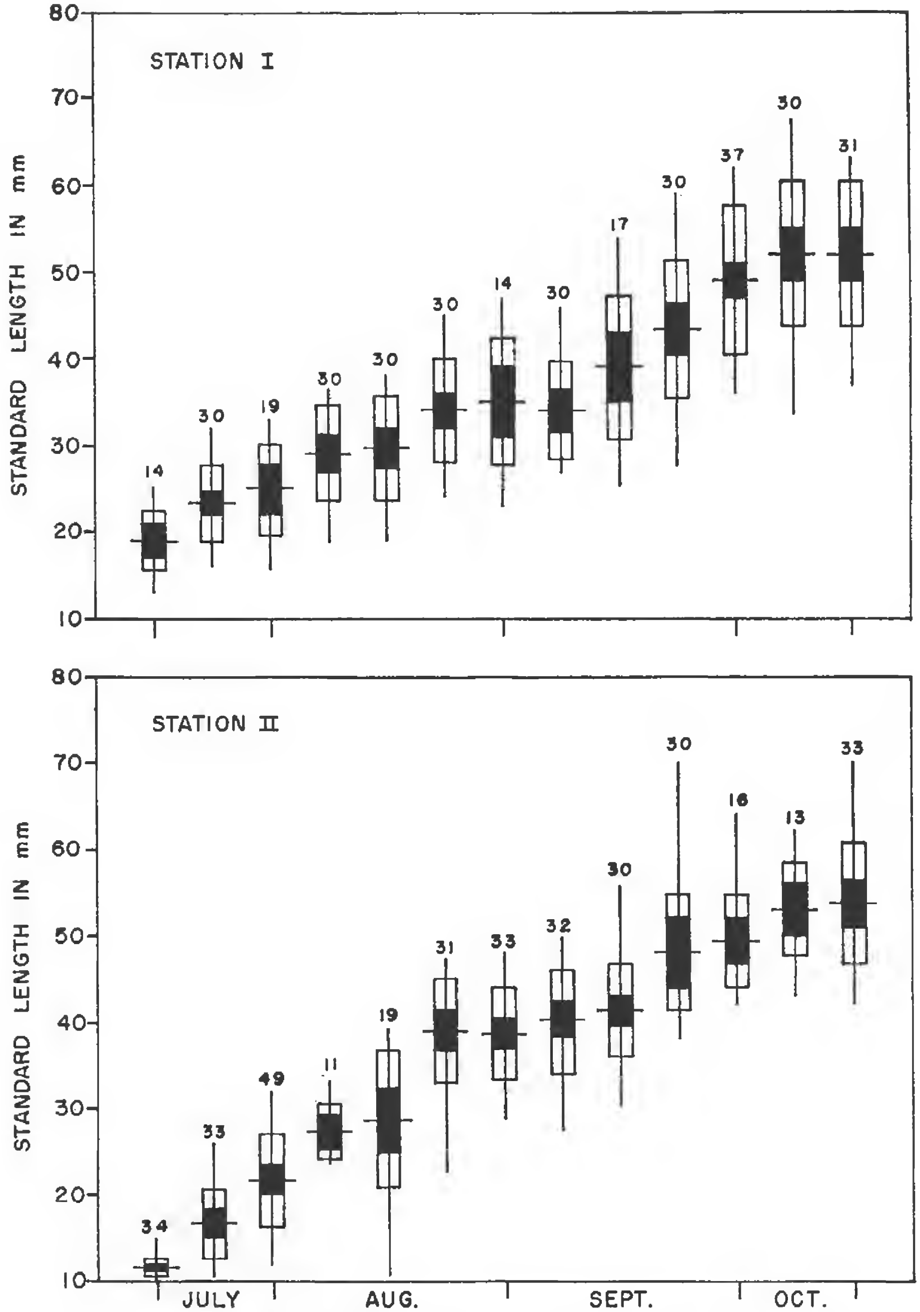


Fig. 15. Average growth of *Menidia menidia* (Juvenile and adult) collected from the lower Pettaquamscutt River from July 11 to October 20, 1962. Method of presentation is the same as given in Fig. 13.

may be misleading because of the admixture of juvenile and adult fish in the catches.

The growth rate for juvenile fish collected from July 11 to August 28 was 7 mm per month. This rate is similar to that for juvenile fish caught at the landward station (Sta. I) in the lower Pettaquamscutt River (Fig. 18). The larger size range of these young fish (Fig. 16) indicated spawning had occurred earlier at the landward station (Sta. III) in the lower Pond. The same phenomenon was noted in the lower River (Sta. I).

The juvenile fish taken from Station IV, lower Point Judith Pond, between July 11 to August 28 demonstrated significant differences between the weekly samples (Fig. 16). Hence the average growth increments are reliable. The sample taken in early August indicates an influx of comparatively small size individuals in the schools (Fig. 16). The samples collected from September 4 to October 20 differed significantly with the exception of the late September samples. These differences between average sizes probably are due to a gradual retreat of the small size fish into deeper water.

The increase in average growth noted between July 11 and August 28 in juvenile fish was 19 mm, a growth rate of 11 mm per month (Fig. 18). These figures compare favorably with data from Station II, in the lower Pettaquamscutt River. The results support the assumption that the growth rate was higher for this species at the seaward stations in both the estuaries.

C. FOOD AND FEEDING HABITS

The analysis of food based upon the stomach contents of the selected species evinced variation in abundance and varieties of prey organisms in the study areas in the two estuaries. The results provided evidence for the assumed possible differences in food resources between a "gradient zone" habitat, Lower Pettaquamscutt River, and "marine zone" habitat, Lower Point Judith Pond (Fig. 3, Tables III and V). Polychaetes were the most important dietary constituent of *Pseudopleuronectes americanus,* while crustaceans comprised the chief food of *Menidia menidia.* In the lower pond, however, 46% of group II (31-50 mm) and 100% of group III (51-80 mm) of *M. menidia* fed on phytoplankton. Heavy sporozoan infection in *P. americanus* was associated with depletion of food in the stomachs. Phytoplankton and suspended organic matter was the principle food of *Brevoortia tyrannus* and no correlation was observed between the size of fish and change in food. The juvenile fish of the species selected for food studies were separated into three size groups ranging between 10-30 mm (Group I), 31-60 mm (Group II), and 61-80 mm (Group III) to study change in food with respect to size of fishes. The minimum size of mature *M. menidia* is considered to be 50 mm (Williams, 1960): this figure was used as limit for Group II (Table V).

1. *Pseudopleuronectes americanus.*

Polychaetes were the basic food organisms, while isopods, amphipods and ostracods were the essential dietary elements of the juvenile fish. Sand, mud and fecal pellets accompanied the food. A preference for larger food organisms was noted with increasing size of the young (Fig. 19).

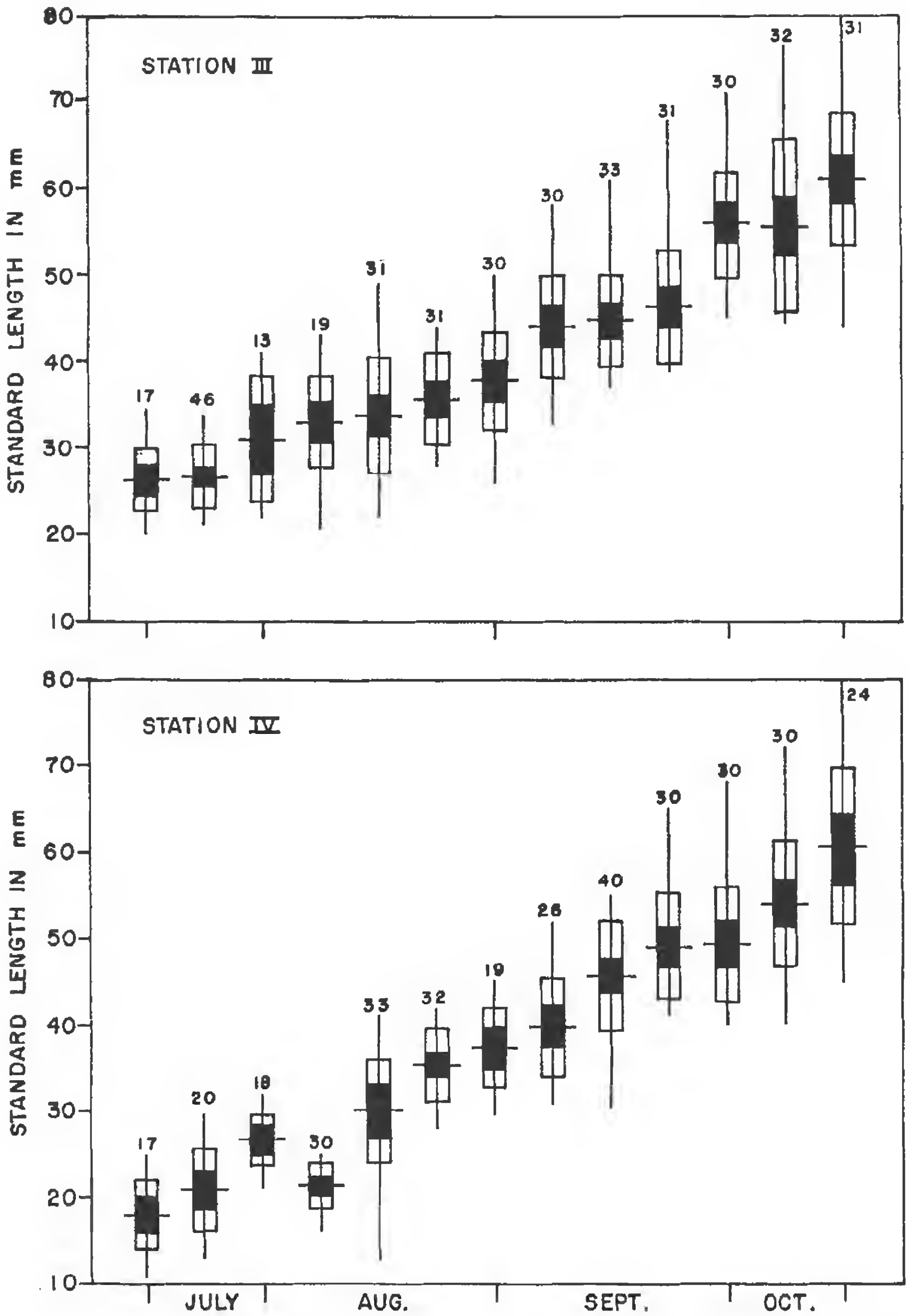


Fig. 16. Average growth of *Menidia menidia* (juvenile and adult) collected from the lower Point Judith Pond from July 11 to October 20, 1962. Method of presentation is the same as given in Fig. 13.

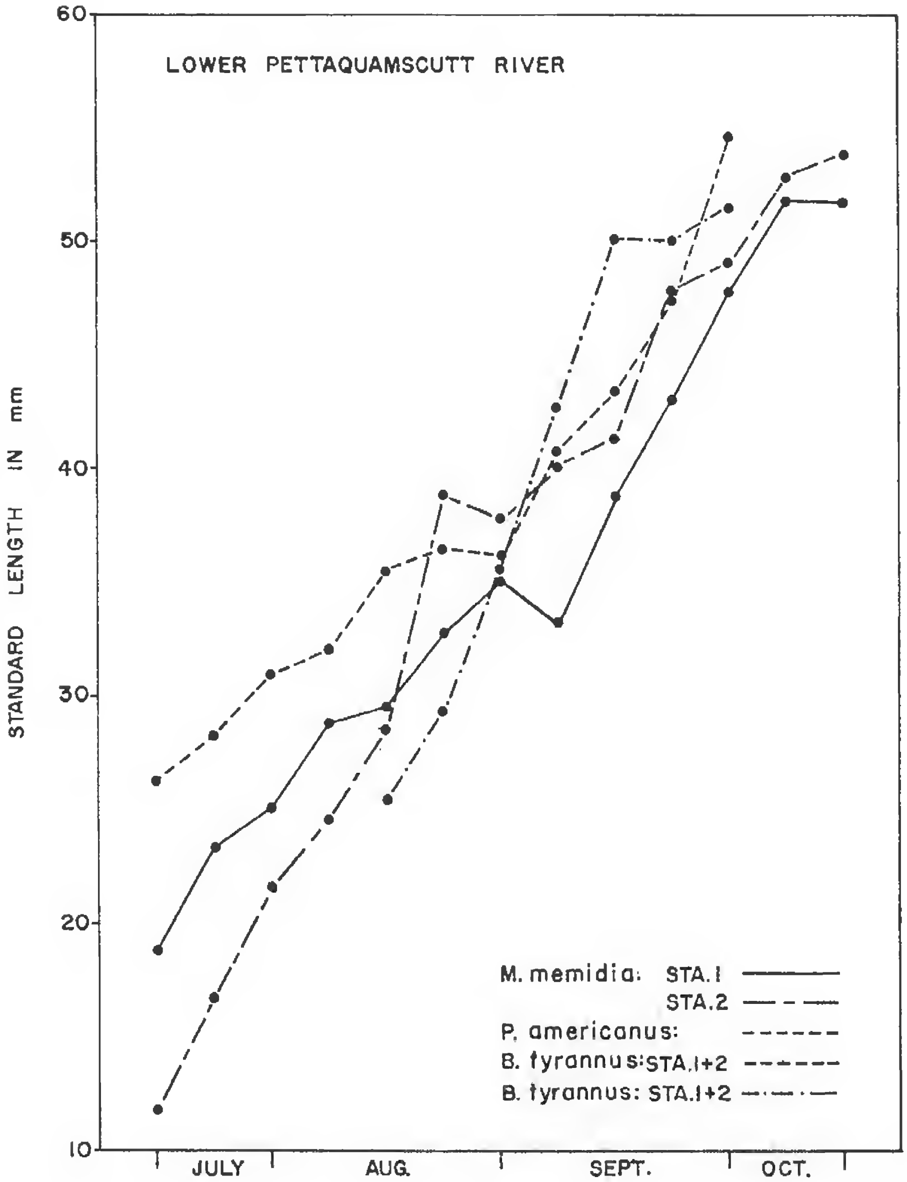


Fig. 17. Rate of growth of *Pseudopleuronectes americanus, Brevoortia tyrannus* and *Menidia menidia* seined from the lower Pettaquamscutt River from July 11 to October 20, 1962.

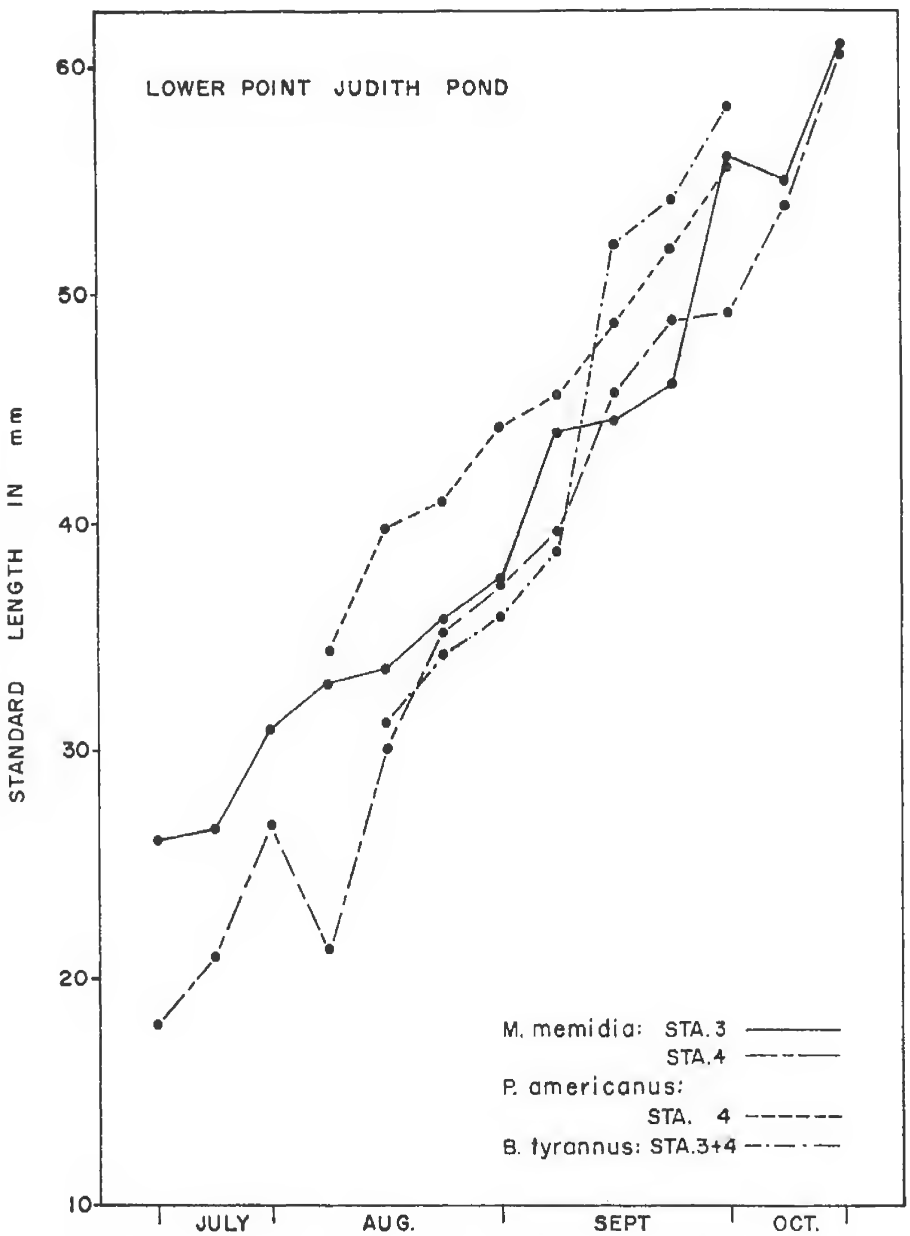


Fig. 18. Rate of growth of *Pseudopleuronectes americanus, Brevoortia tyrannus* and *Menidia menidia* seined from the lower Point Judith Pond from July 11 to October 20, 1962.

Table III. List of food organisms of juvenile *Pseudopleuronectes americanus* from the lower Pettaquamscutt River (Stas. I and II combined), and the lower Point Judith Pond (Sta. IV only) including average number per stomach (A/S), percentage frequency of occurrence (PF), size groups of juvenile fish (in mm) and prey size.

Prey Species	LOWER PETTAQUAMSCUTT RIVER 10-30 mm A/S	PF	31-60 mm A/S	PF	61-80 mm A/S	PF	LOWER POINT JUDITH POND 10-30 mm A/S	PF	31-60 mm A/S	PF	61-80 mm A/S	PF	Prey size (mm)
Phytoplankton	2.2	6.9	2.7	6	—	—	—	—	—	—	—	—	.05-.2
Coelenterata													
Hydroids (Broken)	—	—	—	—	—	—	—	—	—	—	3.25	25	3-5 mm
Nemertean	—	—	—	—	—	—	.25	25	.22	6.8	—	—	4.5-8
Polychaeta:-													
Prionospio malmgreni	2.1	38	.92	12	8.3	47.6	.75	25	.32	22	1	25	5-8
Neanthes succinea	—	—	.08	4	—	—	—	—	14	6.8	.75	25	5-9
Neanthes caudata	—	—	—	—	1.4	13.4	—	—	—	—	—	—	5-7
Neanthes virens	.1	1.7	.3	16	6	73.5	—	—	.24	13.6	—	—	6-15
Drilonereis longa	—	—	—	—	—	—	—	—	.05	1.7	—	—	1.3
Nephthys incisa	—	—	.12	4	.06	6.7	—	—	.05	5.1	.25	25	4.5-8
Lumbrinereis sp.	—	—	.08	2	.27	6.7	—	—	.017	1.7	—	—	6.9
Arabella sp.	—	—	.02	2	—	—	—	—	—	—	—	—	6
Spio sp.	.03	1.7	.18	4	.53	13.4	—	—	.25	11.8	—	—	5-15
Unidentified Polychaetes	.42	24.1	.86	28	10	73.5	1.25	25	.32	13	1	25	5-8
Oligochaeta	—	—	—	—	—	—	.25	25	—	—	—	—	3

Table III. (Continued)

Prey Species	LOWER PETTAQUAMSCUTT RIVER 10-30 mm A/S	PF	31-60 mm A/S	PF	61-80 mm A/S	PF	LOWER POINT JUDITH POND 10-30 mm A/S	PF	31-60 mm A/S	PF	61-80 mm A/S	PF	Prey size (mm)
Crustacea													
Cladocera:-													
Evadne nordmanni	—	—	—	—	—	—	—	—	.1	5.1	—	—	.11
Copepoda:-													
Copepodids	.06	1.7	—	—	—	—	1.5	25	—	—	—	—	.4-.5
Harpacticoida	2.55	29.3	.16	4	—	—	8.5	100	1.58	32	1.75	25	.35-.85
Ostracoda:-													
Cylindroleberis mariae	.72	10.4	.66	12	4.1	6.7	—	—	—	—	—	—	1.2-1.5
Sarsiella americana	.74	12	.22	6	.27	6.7	—	—	—	—	—	—	.9-1.2
Pontocypris edwardsi	48.3	27.6	.4	8	—	—	—	—	—	—	—	—	.6-.8
Cumacea:-													
Cyclaspis varians	.09	5.2	.08	4	—	—	—	—	—	—	—	—	3-4.5
Oxyurostylis smithi	—	—	.1	4	.06	6.7	—	—	—	—	.25	25	3-4.5
Amphipoda:-													
Ampelisca sp.	1.43	29.3	.36	12	.8	26.6	.75	50	.54	17	1.25	50	1.5-4.5
Carinogammarus mucronatus	—	—	.12	2	—	—	—	—	—	—	—	—	4-6
Microdeutopus gryllotalpa	—	—	.08	4	—	—	—	—	.15	5.1	—	—	3-4.5
Gammarus annulatus	—	—	.04	2	—	—	—	—	—	—	—	—	5.5
Corophium cylindricum	—	—	—	—	—	—	—	—	—	—	4.25	25	2-3
Lembos smithi	—	—	.36	8	.2	13.4	.5	25	.64	27.2	—	—	2-4.5

Table III. (Continued)

Prey Species	LOWER PETTAQUAMSCUTT RIVER 10-30 mm A/S	PF	31-60 mm A/S	PF	61-80 mm A/S	PF	LOWER POINT JUDITH POND 10-30 mm A/S	PF	31-60 mm A/S	PF	61-80 mm A/S	PF	Prey size (mm)
Uniciola sp.	—	—	.02	2	—	—	—	—	—	—	—	—	6.5
Amphithoë sp.	—	—	—	—	.2	6.7	.75	50	.2	6.6	—	—	4-7.5
Amphipod - unidentified	—	—	.2	6	.06	6.7	—	—	—	—	—	—	3-4.5
Isopoda:-													
Cyathura carinata	—	—	—	—	.27	20	—	—	—	—	—	—	4.5-8
Edotea montosa	.83	22.4	1.54	34	.27	6.7	.25	25	.57	22	—	—	2-6
Edotea triloba	.1	3.4	—	—	—	—	—	—	.05	3.39	—	—	2-6
Leptochelia savignyi	.03	1.7	—	—	3.2	6	.5	25	1.14	55.6	—	—	1-1.3
Leptochelia sp.	—	—	.42	2	.06	6.7	—	—	.12	5.1	—	—	1.5-2
Idothea viridis	—	—	.02	2	—	—	—	—	.12	5.1	—	—	6
Decapoda:-													
Crago septemspinosus	—	—	—	—	—	—	—	—	—	—	2.5	25	1.5
Chironomid larvae	—	—	.08	4	—	—	—	—	—	—	—	—	2-3.5
Gastropod larvae	.03	1.7	.04	2	—	—	—	—	.05	1.7	—	—	.05-.075
Bivalve larvae	.17	5.2	—	—	.2	13.4	1	50	—	—	—	—	.9-1.5
Invertebrate eggs	1.26	12	.44	4	—	—	2.75	50	—	—	5.25	25	.025-.15
Fish scales	.03	1.7	—	—	.3	13.4	—	—	.48	10.2	—	—	3.5-6
Total number of fish analysed	58		50		15		5		59		12		
Empty stomachs	16		8		3		1		22		2		

THE LOWER PETTAQUAMSCUTT RIVER: From a total of 150 fish studied, 27 had empty stomachs (Table V). The species *P. americanus* feeds normally during the daytime (Pearcy, 1962); all seine hauls were taken only during the day and the small amount of food in the stomachs of the fish probably was due to heavy sporozoan infection. Table III shows the relative importance of various food organisms.

PREY SPECIES: Among the polychaetes, *Prionospio malmgreni* (3-8 mm) was the most important food for all the three size groups of juvenile fish. Phelps (personal communication) found an abundance of this species in Charlestown Pond. *Neanthes virens* (5-15 mm), found in 73.5% of the stomachs in group III, was common as a food in other groups (Table III). A considerable number of polychaetes, fragmented and altered by digestion, were labelled "Unidentified." Other species, *Nephthys incisa, Neanthes caudata, Neanthes succinea, Arabella* sp. and *Lumbrinereis* sp. were less abundant. Often a single individual comprised the bulk of the stomach contents.

Among isopods, the second most important group of food organisms, *Edotea montosa* (2-6 mm), were frequently noted in the stomach. Isopods were relatively easy to identify because of minimum deterioration. *Leptochelia savigni* and *Leptochelia* sp., exhibiting a striking sexual dimorphism and represented mostly by females, were included among other comparatively less important isopod species (Table III).

All young fish ranging between 10-80 mm consumed *Ampelisca* sp., the most common amphipod. Pearcy (1962) reported that *P. americanus* feeds upon *Ampelisca* sp. more than any other amphipod.

Seven other amphipod species, listed in Table III, were absent in stomachs of group I juvenile fish. The amphipods *Carinogammarus, Microdeutopus, Gammarus, Lembos, Unciola* and several unidentified forms were present in the diet of group II, while group III consumed *Lembos, Unciola* as well as some unidentified forms. The ostracods, *Pontocypris edwardsi* (0.6-0.8 mm), were most significant numerically in group I (Table III). Two larger species, *Cylindroleberis mariae* (1.2-1.5 mm) and *Sariella americana* (0.9-1.2 mm), were present in all size groups. The most important components of "miscellaneous" food were harpacticoids, invertebrate eggs, chironomid larvae and fecal pellets.

VARIATION WITH SIZE: Since all collections were made during daylight no day and night variation in feeding was involved. The degree of fullness of stomachs varied with the size of the fish. The percentage of empty stomachs in group I was 21.6% while in group II, it was 13.8% (Table IV). The percentage of stomachs with traces to 25% fullness was higher in group I. In group III only 18 fish were analysed, but the percentage of stomachs with 25-100% fullness was higher than that of group I. The overall picture of stomach fullness does indicate relative increases in stomach contents as a function of body size (Table IV).

With progressive increases in size, young *P. americanus* tended to prefer larger prey organisms. In the group I juvenile fish, *Pontocypris edwardsi,* the smallest astracod species observed, averaged 48.3 per stomach. Eggs and harpacticoids were very abundant in the diet of this group. The smaller polychaete species, *Prionospio malmgreni* (5-8 mm) occurred in 38% of the stomachs with an average of 2.1 per stomach. Larger polychaetes were scarce in the diet (Fig. 19). *Ampelisca* (1.5-4.5 mm), a

comparatively small amphipod, was the only type observed in the diet of this group.

Table IV. Variations in relative degree of stomach fullness of three sizes (in mm) of *P. americanus collected* from the lower Pettaquamscutt River and the lower Point Judith Pond. Table includes number and percentage of stomachs with or without food.

Degree of Fullness	10-30 mm (N)	%	31-60 mm (N)	%	61-80 mm (N)	%
LOWER PETTAQUAMSCUTT RIVER						
Empty stomachs	16	21.6	8	13.8	3	16.6
Trace to 25% fullness	9	12.2	3	5.2	1	5.5
25 to 50% fullness	11	14.8	12	20.7	4	22.2
More than 50% to total fullness	38	51.4	35	60.3	10	55.5
Total	74		58		18	
LOWER POINT JUDITH POND						
Empty stomachs	1	20	22	27.1	2	14.3
Trace to 25% fullness	2	40	16	19.8	5	35.6
25 to 50% fullness	—	—	12	14.8	4	28.6
More than 50% to total fullness	2	40	31	38.3	3	21.4
Total	5		81		14	

In group II young fish the data show diminishing selection for smaller prey organisms and an increasing preference for larger organisms (Fig. 19). The stomachs in group III (61-80 mm) young fish were devoid of eggs, harpaticoids and *Pontocypris edwardsi* indicating least preference for smaller species. Though *P. americanus* is euryphagous, results of stomach analysis indicate that smaller fish tend to select smaller prey species.

Seasonal variations: During the summer months, no apparent variations in prey species with time were noted. Richards (1963) reported that all groups of prey are eaten by *P. americanus* during the summer, while in other seasons particular species such as nemerteans and hydroids are absent in their stomachs. Both of these food groups were present in the stomachs of young fish only from the salt pond estuary.

THE LOWER POINT JUDITH POND: From the lower pond 100 individuals that appeared in catches only at the seaward station were available for study. Twenty-five stomachs were found empty (Table IV), while the remaining 75 were 25% to 100% full. The depletion of food in the stomachs was associated with parasitic infection in the young fish in this estuary (see pp 78).

While polychaetes were the principle food, isopods and amphipods were among the major food items (Table III). Ostracod species were not noted in the diet of fish in the study area in this estuary. The important species and groups that comprised the bulk of the diet of young fish in

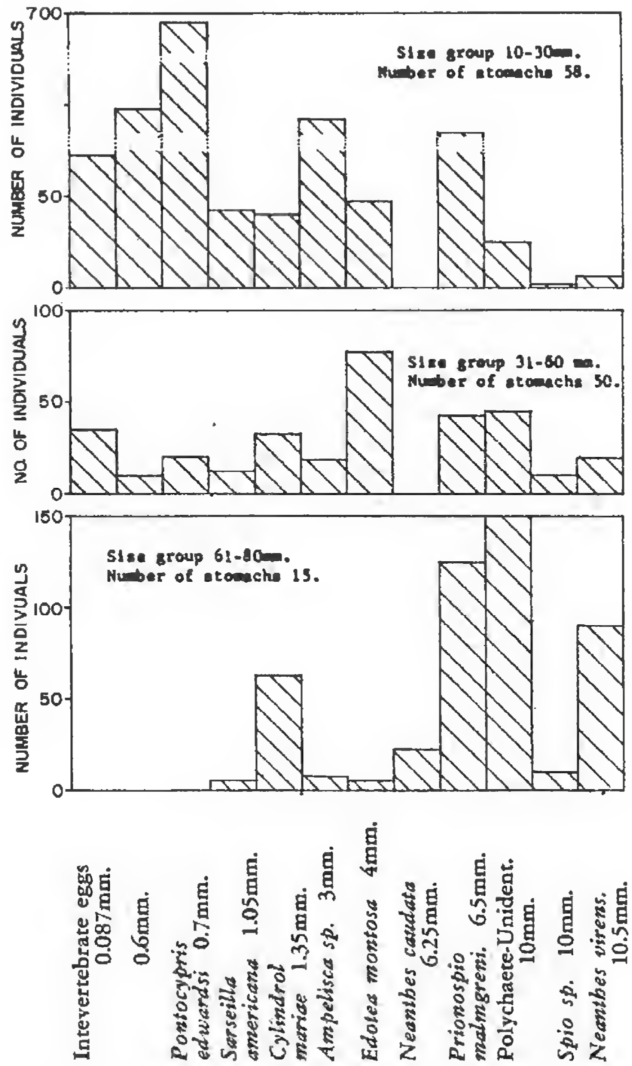


Fig. 19. Variations between different size groups of juvenile *Pseudopleuronectes americanus* and size of the prey organisms collected from the lower Pettaquamscutt River.

the lower Pettaquamscutt River were also present in the food of young fish from the lower pond. Miscellaneous food organisms in the diet including the cladoceran, *Evadne nordmanni,* nemerteans, oligochaete, actinozoa and the polychaete, *Drilonereis longa,* were noted particularly (Table III).

A remarkable feature in the pond estuary was a high percentage of empty stomachs or those with only traces of food (Table IV). According to the general size classification 81% of the young fish were categorized as group II (31-60 mm). The exact picture of size variation between young fish and their prey species could not be traced because of the high percentage of stomachs with little or no food present together with the marked inequality in number of fish in each group. An apparent scarcity in available food in the feeding niches of the lower salt pond may be one reason for a greater number of stomachs containing little or no food.

VARIATIONS BETWEEN THE ESTUARIES: The percentage of empty stomachs of young fish in the lower river was 18% as compared with 25% in the lower pond. The percentage of stomachs with traces to 25% fullness was higher in the lower pond by 14.4% (Table IV). One of the principal groups of organisms, ostracods, was entirely absent in stomachs of young fish in the lower pond. On the average there were fewer important food organisms such as polychaetes, amphipods and isopods per stomach in the lower pond (Table III). Various types of taxonomic groups represented in the diet were also few in the feeding niches of the lower pond environment.

2. *Menidia menidia.*

The species, *Menidia menidia,* demonstrated omnivorous feeding habits. In the lower Pettaquamscutt River the nature of the food varied with size of fish from a mixture of plant and animal food to a strictly carnivorous diet. In the lower Point Judith Pond the young fish were largely dependent upon plant food (Table V and VI). Forty-six per cent of group II (31-60 mm) and all of the group III (61-80 mm) fish ate plant food.

THE LOWER PETTAQUAMSCUTT RIVER: The organisms constituting the important food components of the diet of young fish (10-30 mm) were diatoms, harpacticoids, rotifers, nauplii of *Balanus* sp., and invertebrate eggs (Table V, Fig. 20). Harpacticoids, calanoid copepods, and *Balanus* nauplii comprised the principal diet of groups II and III. Amphipods, isopods and Hymenoptera were also significant as important food components of these two groups.

THE PREY ORGANISMS: While inclusion of diatoms may be considered incidental in the food of group III, these were the essential dietary components for groups I and II. The more commonly occurring species were *Gryosigma spencerii, Gyrosigma* sp., *Grammatophora marina, Nitzschia* sp., *Coscinodiscus* sp., and *Navicula* sp. Invertebrate eggs in 30% of the fish were evidently important food items in the diet of young fish (10-30 mm). Rotifers were present in 35.3% of the fish analysed, mostly of group I. The copepods recorded from the gut content were predominantly adults, including *Paracalanus parvus, Acartia tonsa, Temora longicornis,* and *Pseudocalanus minutus.* The harpacticoids occurring in the diet of 72.7% of the fish examined constituted important food components

Table V. List of food organisms of juvenile and adult *Menidia menidia* from the lower Pettaquamscutt River (Stas. I and II combined) and the lower Point Judith Pond (Stas. III and IV combined) including average number per gut (A/G), percentage frequency of occurrence (PR), size groups of the fish (in mm) and size of the prey species.

Prey Species	LOWER PETTAQUAMSCUTT RIVER						LOWER POINT JUDITH POND				Prey size (mm)
	10-30 mm		31-50 mm		51-80 mm		10-30 mm		31-50 mm		
	A/G	PF	A/G	PF	A/G	PF	A/G	PF	A/G	PF	
Phytoplankton	34.1	89	24.6	66	5.4	51.5	537	100	146	100	.05-.15
Hydroid medusae	.14	4.7	.03	2.4	—	—	—	—	—	—	1.3-1.8 mm
Rotifers	27.5	34.9	2.5	58.5	.85	21.2	—	—	—	—	.07-.1
Polychaete larvae unident.	—	—	.5	2.4	—	—	—	—	—	—	3
Crustacea											
Calanoid Copepods:-											
Acartia tonsa	2.14	14.2	3.42	31.6	31	51.1	—	—	—	—	1.1-1.3
Paracalanus parvus	1.05	11.1	11.8	20.3	31.2	30.5	—	—	—	—	.8-1.0
Temora longicornis	—	—	—	—	.06	3	—	—	—	—	1.3
Pseudocalanus minutus	—	—	—	—	11.2	27	—	—	—	—	.7-.88
Harpacticoida	18.9	71	34.5	100	13.4	70	4.4	76	13	100	.45-63
Cyclopoida:-											
Oithona similis	.76	9.5	25.6	17.1	.61	12.1	—	—	—	—	.45-.6
Copilia sp.	—	—	—	—	.06	3	—	—	—	—	3 mm
Copepod nauplii	1.4	22.2	.17	2.44	—	—	332	100	152	100	.125-.2
Copepodids	.317	11.1	.36	4.8	—	—	33.7	66.8	—	—	.3-.45

Table V. (Continued)

Prey Species	LOWER PETTAQUAMSCUTT RIVER 10-30 mm A/G	PF	31-50 mm A/G	PF	51-80 mm A/G	PF	LOWER POINT JUDITH POND 10-30 mm A/G	PF	31-50 mm A/G	PF	Prey size (mm)
Ostracoda:-											
Pontocypris edwardsi	1.05	14	—	—	—	—	—	—	—	—	.5-.7
Sarsiella americana	—	—	.22	14.6	.12	6	—	—	—	—	.8-1.2
Cumacea:-											
Oxyurostylis smithi	—	—	1	4.75	—	—	—	—	—	—	2.5-4
Cyclaspis varians	—	—	—	—	.27	7.3	—	—	—	—	2.5-3.5
Amphipoda:-											
Lembos smithi	—	—	.365	9.8	.42	15	—	—	—	—	1.7-2.5
Microdeutopus gryllotalpa	—	—	.17	7.3	.06	6	—	—	—	—	2.0-3.0
Carinogammarus mucronatus	—	—	.122	7.3	.03	.01	—	—	—	—	2.7-3.3
Amphithoe sp.	—	—	.049	4.8	—	—	—	—	—	—	1.8-3.1
Ampelisca sp.	.19	6.3	.122	7.3	.97	21.2	.33	19.1	1.12	62.6	1.0-1.75
Isopoda:-											
Leptochelia savignyi	.19	7.9	.56	12.2	.21	3	—	—	.625	47	.55-1.0
Cyathura carinata	—	—	.073	4.8	.166	6	—	—	—	—	2.0-3.0
Tanais cavolinii	—	—	—	—	.18	6	—	—	—	—	1.5-2.5
Idothea viridis	—	—	.073	7.3	—	—	—	—	—	—	3.2

Table V. (Continued)

Prey Species	LOWER PETTAQUAMSCUTT RIVER 10-30 mm A/G	PF	31-50 mm A/G	PF	51-80 mm A/G	PF	LOWER POINT JUDITH POND 10-30 mm A/G	PF	31-50 mm A/G	PF	Prey size (mm)
Cirripedia:-											
Balanus sp. (nauplii)	17.4	60	85	56.1	29.7	45.5	—	—	—	—	.6-1.2
Decapoda:-											
Pagurus sp. zoae	—	—	—	—	—	—	—	—	.47	9.3	.2-3.5
Decapod larvae unident.	.142	4.7	.27	7.3	.06	3	—	—	—	—	1.2-2.5
Insecta:-											
Chironomid larvae	.1	7.9	.122	9.8	.09	6	.071	4.9	—	—	2.0-3.5
Hymenoptera	—	—	.76	31.6	1.27	24.2	—	—	.03	3.1	2.5-5.5
Arachnida	.05	4.7	.025	2.44	.12	6	—	—	—	—	2.5-3.5
Bivalve larvae	.05	6.4	—	—	—	—	—	—	—	—	.6-1.2
Gastropod larvae	.49	11.1	.29	12.2	—	—	—	—	—	—	.075-.125
Invertebrate eggs	17	46	5.98	26.9	4.25	15.2	13.8	40.5	.97	31.3	.025-.05
Fecal pellets	.05	1.59	—	—	—	—	.166	7.15	.5	15.4	.15-.25
Fish scales	.86	42.9	.98	41.5	1.21	33.4	—	—	—	—	1.5-2.5
Fish eggs	.05	3.18	.315	7.3	.18	9	—	—	—	—	.8-1.1
Total number of fish analysed	69		45		36		45		34		
Empty guts	6		4		3		3		2		

in all size groups. The cyclopoid, *Oithona similis,* was significant in group II fish.

The isopod, *Leptochelia savignyi,* was eaten by all size groups of fish. Other isopod species consumed by young and adult fish (31-80 mm) were, *Cyathura carinata, Tanais cavolini,* and *Idothea viridis. Ampelisca* sp. was the only amphipod in the gut contents of group I fish (Table V), while the five species listed above were consumed by groups II and III. Hymenopterous insects significantly occurred in groups II and III and often comprised the bulk of the gut contents. Although the hymenoptera was well represented it is doubtful if this group, mostly represented by ants, serves as a regular source of food. These insects are probably incidentally introduced in water. The chironomid larvae, which usually occur in fresh water environments, are swept down into brackish water from the fresh water area. These were fed on by all three size groups. Decapod larvae, cumacids, gastropod larvae and fish eggs were the prominent "miscellaneous groups". The prey including larger organisms, such as amphipods, isopods and gastropod larvae were predominantly fed upon from the substratum or *Zostera* and *Ruppia* leaf blades.

VARIATION WITH SIZE: No day and night variations in feeding are known in *M. menidia.* The degree of fullness of the gut in various size groups indicates that fish were caught during the active feeding period which was always during the daylight hours (Table VI). Though the usual food for the larger group (51-80 mm) was scarce, there was an apparent indication of increase in gut fullness with increase in size of the fish (Fig. 20).

Phytoplankton as an important dietary component became less and less important with progressive growth of the young fish (Table V). In group I (10-30 mm) young fish largely depended upon small size prey organisms. Rotifers (.07-.1 mm) average 27.5 per gut while harpacticoids (.45-.63 mm), occurring in 71% of the gut, averaged 18.9 per gut. Invertebrate eggs and Balanus nauplii were present in 46% and 60% of the fish examined and averaged 17 and 17.4 per gut respectively. Other prey organisms including the larger crustaceans were insignificantly represented in the gut contents.

In group II (31-50 mm) fish phytoplankton were less important as diet, harpacticoids occurred in 100% of the fish examined, copepods and *Balanus* nauplii occurred in larger numbers as compared with the amount consumed by group I fish (Fig. 20).. Invertebrate eggs and rotifers, important dietary components of group I fish, were insignificant in group II fish. In addition some species of amphipods and isopods became increasingly important in the diet (Table V). In group II larger size prey organisms were characteristic of the diet indicating an apparent preference for larger prey with the increase in size.

The group III (51-80 mm) fish followed a similar trend in the dietary shift demonstrating greater dependence on larger food organisms. An average of 5.4 phytoplankton per gut seem to be incidently ingested along with other prey. Copepods were the most important food component. The species *Acartia tonsa* and *Paracalanus parvus* were highest in abundance in the gut contents and averaged 31 and 31.2 per gut respectively. The insects, Hymenoptera, ocurred in 24.3% of the guts analysed. Isopods and amphipods were also common in this group (Table V). There was

Table VI. Variation in relative degree of gut fullness in three size classes of *Menidia menidia* in the lower Pettaquamscutt River and the lower Point Judith Pond. Table shows the number (N) and percentage (%) of gut with or without food. Figures with asterisk indicate fish that ate phytoplankton.

Degree of Fullness	10-30 mm (N)	10-30 mm (%)	31-50 mm (N)	31-50 mm (%)	51-80 mm (N)	51-80 mm (%)
LOWER PETTAQUAMSCUTT RIVER						
Empty gut	6	8.7	4	8.9	3	8.3
Traces to 25% fullness	15	21.7	11	24.4	15	41.6
25 to 50% fullness	21	30.4	7	15.6	11	30.6
More than 50% to total fullness	27	39.2	23	51.1	7	19.5
Total	69		45		36	
LOWER POINT JUDITH POND						
Empty gut	3	6.7	2	3.2	—	—
Traces to 25% fullness	5	11.1	4	6.4	—	—
25 to 50% fullness	16	35.1	15	23.8	—	—
More than 50% to total fullness	21	46.1	13 29*	20.6 46	42*	100
Total	45		63		42	

however no apparent change in the supply of food during the study period, covering summer and early fall.

LOWER POINT JUDITH POND: The fish in the lower pond largely depended upon phytoplankton as diet. The group I and over 50% of group II fish ate mixed plant and animal food, while 46% of group II and all the fish of size group III consumed phytoplankton.

PREY ORGANISMS: The major food items observed in the gut contents were: phytoplankton, copepod nauplii, copepodids, invertebrate eggs and to some extent harpacticoids. Inclusion of phytoplankton, as either an important component or the entire diet, was apparent in all the three size groups (Tables V and VII).

The results of the analyses of plant food (Table VII and Fig. 21B) indicate that there was an increase in volume per gut with increase in size of fish and an average of 768 cells/mm^3. The plant food consisting chiefly of littoral benthic diatoms included mostly *Gyrosigma spencerii* and *Gyrosigma* sp. in addition to less abundant species as mentioned in the description of the vegetable diet of the fish in the study area of the river estuary. Copepod nauplii averaged 332 per gut in group I and 152 in group II. Copepodids and invertebrate eggs found in over 66% and 40% respectively in size group I (10-30 mm), were insignificant in group II. There was an apparent scarcity of larger crustacea, and other taxonomic groups. The prey, *Ampelisca* sp., chironomid larvae and fecal pellets in group I were listed as "miscellaneous food" items, while in the group II,

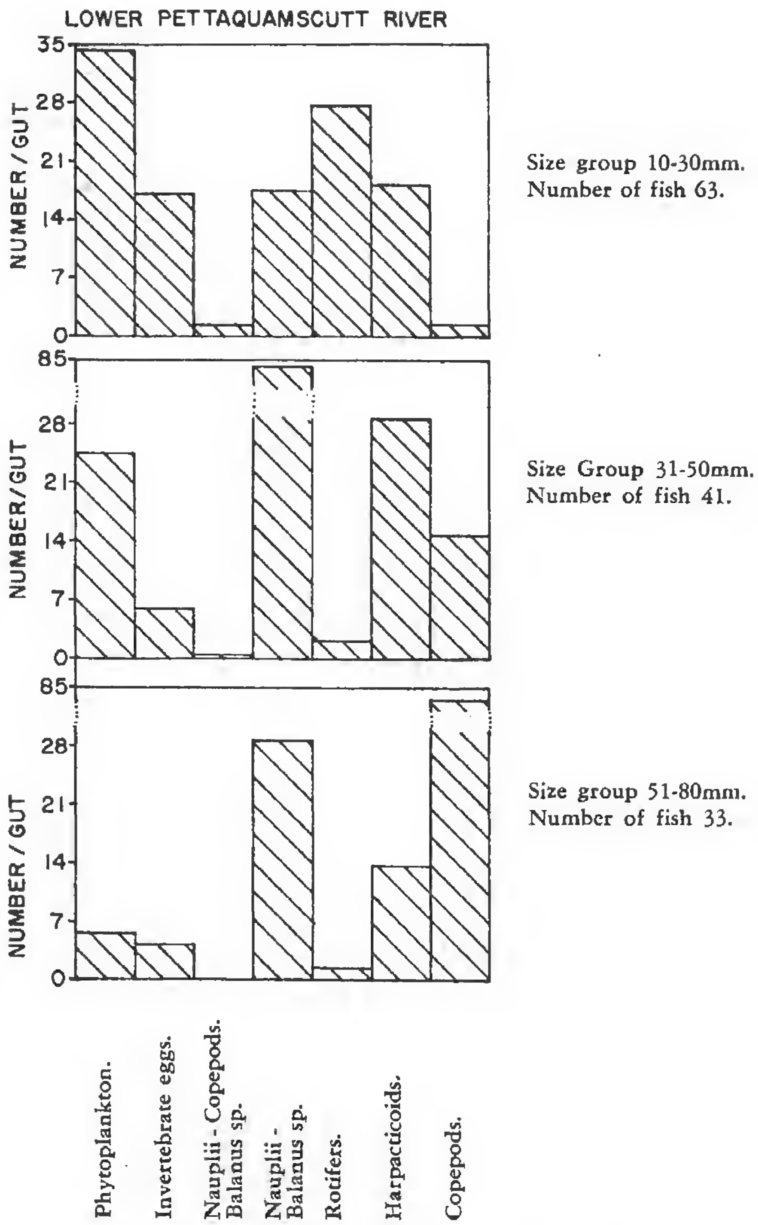


Fig. 20. Variation between size groups of *Menidia menidia* and size of the prey species (given against each bar).

Table VII. The average volume and number of cells per gut in various class sizes of *Menidia menidia* that ate only phytoplankton in the Lower Point Judith Pond.

Class size in mm	Average Vol. in cc/gut	Average Number of cells/cc	Average Number of cells/gut
30-40	0.04	768,000	29,720
40-50	0.05	768,000	39,936
50-60	0.125	768,000	96,000
60-70	0.218	768,000	167,424
70-80	0.214	768,000	164,352

Leptochelia savignyi, Pagurus sp. zoeae, Hymenoptera and fecal pellets represented a similar category.

VARIATION WITH SIZE: The analysis of the gut contents showed the presence of two major food components; the minute developmental stages of crustacea and phytoplankton (Table V, Fig. 21). The microscopic mixed plant and animal food perhaps suited the feeding habits of the small size (10-30 mm) fish. The larger size fish (31-80 mm) were possibly unable to feed on minute organisms effectively in the pelagic environment, hence picked up food from the substratum as mouthfuls which contained diatoms, organic debris and fecal pellets (Tables V and VII). Brodski and Jankovskaya (1935) indicated a similar behavior in the eastern sardine, *Sardinops melanosticta,* which feeds effectively on phytoplankton in the absence of zooplankton, the normal diet of this species. A similar situation was non-existent in the lower river. Here the larger fish ate larger crustaceans and other food organisms. The inclusion of phytoplankton in their diet seemed to be incidental.

3. *Brevoortia tyrannus.*

A controversy exists regarding the nature of the primary food of *Brevoortia tyrannus.* Peck (1894) examining the food of juvenile and adult fish from Buzzards Bay, Massachusetts, during the summer period, described it as consisting of suspended organic matter and phytoplankton, with small crustaceans as supplementary food. Peck gave no quantitative data for plant matter in his food habit studies. Richards (1963) described the food of young *B. tyrannus* during winter as consisting primarily of crustaceans without any inclusion of plant food. Other workers reported that the diet was composed of oozy mud (Verrill, 1871), and others as plant debris, miscroscopic plants and small crustaceans (Goode, 1880; Bigelow and Schroeder, 1953). Richards (1963) did not account for any seasonal variation in the basic diet. By combining data and observations from this and Peck's summer studies, together with Richards' winter studies it seems evident that seasonal changes in feeding habits are indicated.

In the 150 fish of this species examined from each estuary most of the stomachs had only traces of food while the gizzards were always full (Table VIII).

The high percentage of empty stomachs may have been due to a

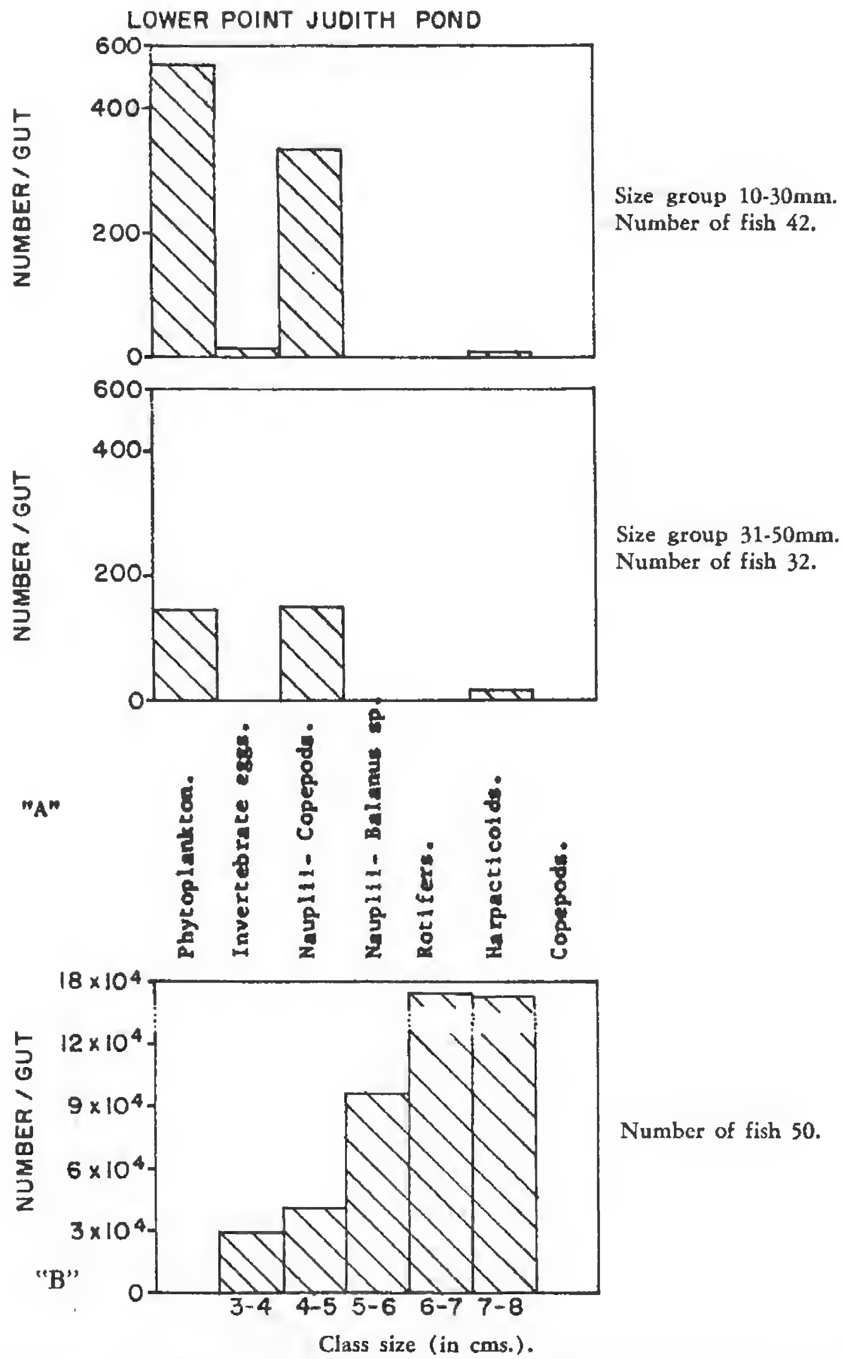


Fig. 21.A. Variations between size groups of *Menidia menidia* and size of the prey species.

Rig. 21.B. Variations in number of phytoplankton per gut relative to class sizes of *Menidia menidia.*

rapid transfer of food to the gizzards since these latter organs were always found full.

The stomach contents were comprised chiefly of unidentifiable organic matter including soft organic or so-called "oozy mud" and unicellular algae, predominantly *Peridinium* sp. Diatoms were uncommon and harpacticoids, copepod nauplii, and copepodids occurred rarely in samples from both the estuaries. Peck (1894) stated, while the only food noted was unicellular algae, polychaetes and crustaceans were altogether absent in day samplings. These observations are analogous to the findings of the present study. Fifteen different types of organisms were identified to species or genera and groups represented by dinoflagellates, *Peridinium, Dinophysis, Glenodinium,* diatoms, *Gyrosigma spencerii, Gyrosigma* sp., *Acnathes, Gramatophora, Navicula, Coscinodiscus, Rhizosolinia,* and other groups included copepod nauplii, copepodids, harpacticoids and infusorians. These organisms constituted just a small fraction of the diet in comparison to the free organic matter. There was no change in type of food with progressively increasing size of the young fish (Richards, 1963). The analogous earlier observations may have discouraged serious quantitative studies, because the material observed in summer period does not lend itself to a reliable quantitative determination.

Table VIII. Variations in the relative degree of stomach fulless of three class sizes (in mm) of juvenile *Brevoortia tyrannus* from the lower Pettaquamscutt River and the lower Point Judith Pond. Table represents number (N) and percentage (%) of stomachs with or without food.

Degree of stomach fullness	10-30 mm (N)	(%)	(N) 31-60 mm	(%)	(N) 61-80 mm	(%)
LOWER PETTAQUAMSCUTT RIVER						
Empty stomach	1	3.7	18	16.1	—	—
Traces to 25% fullness	23	85.2	74	66	9	81.7
25 to 50% fullness	3	11.1	13	11.6	2	18.2
More than 50% to total fullness	—	—	7	6.3	—	—
Total	27		112		11	
LOWER POINT JUDITH POND						
Empty stomachs	2	5.3	9	9.9	—	—
Traces to 25% fullness	29	76.3	53	58.2	15	71.1
25 to 50% fullness	7	18.4	24	26.4	6	28.9
More than 50% to total fullness	—	—	5	5.5	—	
Total	38		91		21	

D. PREDATORS AND PARASITES

Large size fish were uncommon in the seine hauls. The stomachs of adult *Roccus americanus, Opsanus tau, Tautoga onitis, Menidia menidia* and juvenile *Caranx crysos* (40-60 mm) captured during seining were examined. Only *Opsanus tau, Caranx crysos* and *Menidia menidia* were found feeding on juvenile *Anchova mitchilli* and *Menidia menidia.* No valid picture of the overall predation can be traced because adult fishes are least vulnerable to shore seining. Piscivorous birds, *Larus* sp., the herring gull, *Sterna* sp., the common tern and *Phalacrocorax* sp., the cormorants, were observed feeding on fry throughout the survey period in the lower parts of both estuaries. Pearcy (1962) reported an abundance of cormorants in the Mystic River estuary during late summer and fall, and Steven (1933) in England showed 40% of the diet of cormorants to be flatfishes.

Infections of sporozoan parasites was surprisingly common in *Pseudopleuronectes americanus* and *Osmerus mordax.* Ectoparasites were uncommon and were only found infesting *Alosa pseudoharengus, Fundulus heteroclitus* and *F. majalis.* These were represented by *Argulus funduli, Argulus* sp. and *Caligus* sp. Endoparasites were observed in *B. tyrannus, P. americanus,* and *M. menidia* during food analysis, including nematodes, cestodes and sporozoans. The sporozoan parasite, *Glugea hertwigi,* was visible through the translucent body wall of *Osmerus mordax,* while equally heavy infection was also observed in *P. americanus. Glugea hertwigi* occurred as white globules attached to gut epithelium or infesting the outside walls of the alimentary tracts. In heavy infection the lumen of the alimentary tracts were either fully loaded with *Glugea* colonies or these were thickly embedded on the outside body walls. In instances of light infection a few scattered globular structures were loosely attached inside or dorsal to the alimentary tracts. In all cases of heavy infection alimentary tracts were devoid of food, and indicated greater susceptibility to other parasites. Table IX shows the degree of infection in *P. americanus.*

Table IX. Number (N) and percentage (%) of juvenile *Pseudopleuronectes americanus* infected with *Glugea hertwigi* collected from the lower Pettaquamscutt River and the lower Point Judith Pond.

Class in mm	Number of fish	Light Infection (N)	Light Infection (%)	Heavy Infection (N)	Heavy Infection (%)
LOWER PETTAQUAMSCUTT RIVER					
10-30	244	29	11.9	11	4.9
31-60	116	7	6	3	2.6
61-80	36	3	8.3	—	—
LOWER POINT JUDITH POND					
10-30	5	1	20	—	—
31-60	81	13	18	6	7.4
61-80	14	3	21.4	1	7.1

The data indicate that a considerable number of fish were infected. Through accurate estimation of mortality may require extensive sampling, these data suggest a high mortality may have occurred especially in group I (10-30 mm). Kudo (1947) and Duijn (1956) found that a host dies when heavily infected with *Glugea hertwigi* because of a degeneration of the large number of cells attacked.

VI. DISCUSSION

Spring and summer seasons mark the spawning activities in most of the species of fishes in New England waters (Merriman and Sclar, 1952; Wheatland, 1956; and Herman, 1958). Following the larval phases of growth, the young fish are faced with the problem of protection from predators and a search for abundant food. At this stage estuaries become important as nursery grounds for young fishes.

A significant influx of juvenile immigrant species from offshore and from lower latitudes and the emigration of anadromous forms was noted as temperature increased during early summer (Fig. 7). Although the abundance of fishes followed the general pattern of rise and decline in temperature, no correlation was observed between maximum temperature and maximum abundance (Fig. 7). The differential temperature tolerance in various species may be a contributing factor for a lack of correlation. Warfel and Merriman (1944) have reported that maximum temperatures are not accurate indicators of a great number of species.

Salinity is a determining factor limiting the distribution of fishes within the various segments of an estuary. The stenohaline species, especially the fresh water forms, may be limited within a narrow range of salinity. Marine forms are usually more euryhaline and are able to withstand wide ranges in salinity (Herre, 1956). A few brackish and fresh water fishes occurred in both the study areas (Table I) where salinity ranged between 10-32 o/oo and 28-32 o/oo in the lower river and the lower pond respectively. Even at Bridgetown Bridge, where salinity varied between 9.8 - 15 o/oo mostly marine forms were captured. The only fresh water species recorded was *Micropterus salmoides,* collected from the Middle Bridge area (Sta. II, Fig. 1). Adolf (1925), in discussing the tolerance of marine and fresh water organisms, suggested that marine organisms are better adapted to changes in the osmotic environment than are fresh water forms. The lack of relationship between the fluctuation in salinity and fluctuation in marine fish population is indicative of the fact that these forms can adjust to wide salinity changes in the environment. Further, the number of marine species recorded from the lower river was one and a half times higher than those captured in the lower pond (Table I) indicating an apparent preference for an area with pronounced variation in salinity (Figs. 4 and 5).

The species, *Pseudopleuronectes americanus, Brevoortia tyrannus* and *Menidia menidia,* which were used for detailed study, also gave evidence of changes in distributional behavior with respect to spawning seasons, age and thermal tolerance. The juvenile *P. americanus* of zero year class were caught mostly at lower stations in shoaler water (Table I, and pp. 15). As the larvae of this species grow they move down stream (Bigelow and Schroeder, 1953; Pearcy, 1962) and occupy stations closer to the mouth of estuaries during summer. The preference for shoaler areas with higher temperature (Figs. 6 and 12 and pp. 15) explains why a few individuals

caught at upper comparatively deeper stations in both localities were either mostly or all second year class fish. Huntsman and Sparks (1924) reported a higher incipient lethal temperature for smaller flounder than for larger ones. The difference in temperature tolerance may explain why larger fish may prefer deep water in summer.

The influx of *Brevoortia tyrannus* in the two estuaries was apparent because of the great abundance of small fish at landward stations during September. Although the schools of "precise size" individuals of this species move up and down the estuaries during the nursery period, the presence of a few fish of diverse sizes only at the seaward stations in October suggests an outward migration at this time of the year (Figs. 10 and 11).

The species, *Menidia menidia,* forms schools of similar sized individuals (Shaw, 1960) and because fish of all sizes, above 2.5 cm (1 in.), occur all the year round (Bigelow and Schroeder, 1953) patches of various size groups were found at all the stations. Because of extreme adaptability of this species to changes in temperature and salinity its abundance was markedly high at all the four stations. The measure of total abundance and distribution depends upon the reliability of catches. The catch reliability in turn may depend upon a number of factors, such as distance from the fresh water source, the tide and especially the temperature, which is the dominant factor. Day (1951) reported that any one factor cannot be the sole determinant of the distribution of organisms in estuaries. Although the total abundance and distribution are markedly influenced by temperature fluctuations, it is suspected that slight changes in temperature caused marked fluctuations in the catches (Fig. 7). The phenomenon seems to be a recurring process of overcrowding and dispersal. Such a pattern is well illustrated in the total catches in the lower Pettaquamscutt River. As Warfel and Merriman (1944) suggested, that under optimum living conditions population density may reach a super-saturation point at which time the ensuing population pressure forces a dispersal followed by another build up process.

No relationship was observed between the total number of species and the total number of individuals occurring at any one time. These data demonstrate (Fig. 7) that there were peaks in numbers of individuals occurring in late August, while the largest numbers of species in general were recorded during September in both the areas under study. The migrant species such as *Lutjanus griseus, Trachinocephalus myops* and *Chaetodon ocellatus,* enter Rhode Island waters as stray individuals from remote spawning centers quite late in summer. The late entry of these fishes contributed markedly to increases in number of species. However, because there were too few individuals, total abundance in these areas remained unaffected. Other species such as *B. tyrannus* that spawn in coastal and offshore waters, and *Alosa pseudoharengus,* that spawn in some Rhode Island estuaries appear in schools sporadically following the temperature rhythm and tend to influence the total catches.

In addition to physical and chemical variables and general migration trends of many species, the environments, characterized by various types of substrates and variable profusion of benthic plant life, serve to attract or discourage large populations of fishes. The greater number of species and individuals of most species preferred habitats at Harbor Island, in the lower pond and at Middle Bridge, in the lower river, where luxurious

growth of Zostera-algal communities occur. These habitats especially in the Middle Bridge area, in the lower river, apparently provide plant cover and abundant food supply, the primary needs of the juvenile fishes, and are therefore, major attractions to large populations of considerable number of species of young fishes (Table 1). A fewer species of young fishes frequented the Bridgetown Bridge area, in the lower river, and the seaward station, in the lower pond, where a paucity of plant life prevails. The data for growth and food studies of young fishes were combined for both the stations in each estuary. Hence, these data represent the consequences of all the environmental influences in each estuarine system. A higher profusion of benthic plant life in the Middle Bridge area, is reflected in beter conditions for growth of young fishes and greater abundance of food in the lower river as compared to those in the lower pond.

Another useful aspect of the habitats with profusion of benthic plant life, is a case of mimicry exhibited by species including *Tautoga onitis* and *Tautogolabrus adspersus,* a useful adaptation for protection in these habitats.

The growth studies were conducted during summer season, the period of thermal maximum. The higher temperature results in increased metabolic activity (Prossor and Brown *et al.,* 1962), and particularly influences the rate of growth in poikilothermic animals including fishes (Rounsefell and Everhart, 1953).

Although the lower river was preferred by most species and held a greater abundance of prey organisms, no variation in average growth was observed for *P. americanus* in both the study areas. Probably due to small sample sizes the variation in growth did not become apparent. However, the growth increments were significant (Figs. 13, 17 and 18). The average growth of the young fish from the lower river and the lower pond compares favorably with growth of juvenile *P. americanus* in the Mystic River estuary, an area considered to be highly productive (Pearcy, 1962).

The statistical analysis of growth data of juvenile *B. tyrannus* showed that two distinct groups in each estuarine system studied (Fig. 14) The first group, appearing from mid-August to mid-September comprising four samples of "precise size" individuals, showed significant and statistically adequate growth in each of the study areas. The rate of growth per month for this species in the lower river was double that of the fish from the lower pond (Fig. 14). Although there is marked irregularity in sample sizes because of the schooling habit of this species, comparative food studies of the feeding niches also reflect the better environmental conditions in the lower river. The rest of the samples were composed of individuals with diverse size range which perhaps had strayed off from the various schools during emigration. The growth rates in such samples markedly differed from the previous samples (Figs. 17 and 18). McHugh *et al.* (1959) have found that a single rate of growth for this widely ranging species in an estuary is untenable.

Although no comparable growth study of *Menidia menidia* is available, the growth data of this small sized species (Figs. 15-18) indicate that significant growth increments occur from early July to early September. Indications of variation in growth were observed in the two estuarine environments, and between the two stations within each individual estuary (Figs. 15-18). The higher rate of growth in the lower river is indicative of a higher productivity in comparison to that of the lower pond. This

correlation is also corroborated by environmental and food habit studies (Table V and pp. 15). The differences in variation occurring between the stations in each estuary were probably due to late spawning at seaward stations. The higher rate of growth at seaward stations (Figs. 17 and 18) indicated smaller fish of the same year class grow faster.

The success of feeding niches in the two estuarine systems studied depends upon the presence of abundant, palatable food and habitat conditions. The food resources in the lower Pettaquamscutt River, an area with conditions varying from neritic to brackish water and profusion growth of plant life with attendant epibiota, were comparatively abundant and suited to the food habits of all size groups of progressively growing fishes. In the lower Point Judith Pond where neritic conditions prevail, the less abundant animal food was reflected in the low diversity of prey organisms (Tables III and V). The higher percentage of empty stomachs in *Pseudopleuronectes americanus* and presence of phytoplankton as substitute diet or "forced diet" in the gut contents of *Menidia menidia* may account for the low efficiency of the trophic environment in the lower pond. The food study of the individual species further illustrated this variation in the trophic picture.

The prey of *P. americanus* represented a wide variety of organisms from both the pelagic and benthic environments (Table III). Although *P. americanus* is a euryphagous species (Pearcy, 1962), the three arbitrarily selected groups from the lower river demonstrated a preference for larger and more varied types of food organisms, with increase in size (Fig. 19 and Table III). The small juvenile fish (10-30 mm) largely ate harpacticoids, *Pontocypris edwardsi,* invertebrate eggs, and few species of larger organisms. The inclusion of large sizes and the diverse nature of the prey including polychaetes, amphipods and isopods in the diet of young fish of size groups 31-60 mm and 61-80 mm is doubtless due to a greater adaptability of the larger young fish to capture larger and more varied types of food organisms. The stomach fullness method indicated a greater percentage of full stomachs, noted in the lower river, as function of size.

While the essential dietary components were present in the food components of *P. americanus* from the lower pond, the quantity and diversity in the prey organisms was low in comparison to those occurring in the lower river (Table III). Shelbourne (1953) in the plaice, *Pleuronectes platessa,* and Pearcy (1962) in *P. americanus* have observed diurnal feeding behavior. Since the catches represent day samplings, a high percentage of stomachs with little or no food, observed in the lower pond, indicate that there was a low abundance of prey organisms. Any interpretation on the basis of higher digestive rates in one estuary than the other may be erroneous as the fish of the same species were caught at the same time of the day, with lesser food in the stomachs in one environment as compared to that in the other environment. From these observations it would seem that in some river estuarine systems with a distinct salinity gradient, environmental conditions are apt to be more successful in terms of feeding niches for young fish than the estuarine environments with near neritic conditions such as the lower pond. Pearcy (1962) compared his results of production of young *P. americanus* from the Mystic River estuary with those of Richards (1963) from Long Island Sound and contended that seventy times higher values for the estuary point to higher productivity in the small estuaries as compared to the near Sound area.

The data obtained for *Menidia menidia,* an omnivorous fish, allowed further insight into the trophic environment of the feeding niches, in both the study areas. While the diet of this species in the lower river contained a mixture of plants and animals, the fish demonstrated largely or wholly a dependence upon phytoplankton in the lower pond. The food of *M. menidia* which was rich in phytoplankton for small size (10-30 mm) fish in the lower river, essentially was composed of phytoplankton, rotifers, harpacticoids and calanoid copepods, *Balanus* nauplii and invertebrate eggs. With a successive increase in the size of the fish, the phytoplankton in the diet became negligible. Calanoids, harpacticoids and *Balanus* nauplii were the important food components for larger fish (31-80 mm). It seems that the smaller fish preyed upon minute and less mobile food organisms including phytoplankton. Later with increased size and speed these fish could feed on a great variety of larger and more mobile food organisms. Bhattacharyya (1957) reported a similar gradual dietary change from vegetable food to a carnivorous diet in postlarval herring (35 mm).

The small size fish consumed more phytoplankton in the lower pond due to an apparent lack of minute prey organisms (Table V). Forty-six per cent of the size group 31-50 mm and all of size group 51-80 mm fish ate plant food. One possible interpretation may be that due to a scarcity of carnivorous food, the fish would be forced to seek a substitute diet or so-called "forced diet." In this case the substitute diet was phytoplankton, primarily benthic littoral diatoms, fecal pellets and detrital material (Brodski and Jankovskaya, 1935). There is no information to the author's knowledge concerning the nutritive value of such food. However there was indication of comparatively slow rate of growth in the pond estuary where fish largely depended upon phytoplankton. The excessive grazing by these fish on plant food, the only available substitute, may be preparatory for the winter season, when active feeding is probably minimal.

There is no well defined study on the food habits of *Brevoortia tyrannus.* Controversy exists on the nature of its primary food and feeding habits. The results of the present study and comparison with other available data on the food habits of this species indicate that the primary food during summer and fall is phytoplankton and suspended organic matter while in winter crustaceans constitute the basic diet (Peck, 1894; Richards *et al.,* 1963). The diet of this species according to the present study includes dinoflagellates, diatoms, and a very large fraction of unidentifiable organic matter (see pp. 76). The average and percentage occurrence methods employed for analysis of food for other species were obviously not useful for this type of material. The stomach fullness method showed most of the stomachs were empty or traces to 25% full (Table VIII). Gizzards and intestines were always full which indicated that food transfer from stomach to the gizzards probably took place in a very short time.

Since the diet of *B. tyrannus* in summer and fall included phytoplankton and suspended organic matter, its abundance in the pond estuary can immediately be realized from the food habits of *M. menidia.* Furthermore the rates of growth in both estuarine systems favorably compare with data from other studies (Welsh *et al.,* 1924; McHugh *et al.,* 1959) and indicate that the nutrition for this species must have been adequate in both environments.

The predators and most parasites did not seem to harm the populations of young fishes. However the sporozoan parasites, *Glugea hertwigi,*

common in *Osmerus mordax* and *P. americanus*, indicated harmful effects in the latter species. The comparative higher infection and markedly low catches of *P. americanus* in the lower pond to an extent of almost one-fourth the collections from the lower river point to possible mortality that may have incurred (Tables I and IX). Almost total depletion of food in heavily infected stomachs indicated feeding may have been adversely affected by presence of these parasites, but average growth in both the study areas did not show any variation, possibly due to an inequality in sample sizes. But in all cases of heavy infection, the digestive tissues were found badly attacked and showed signs of obliteration. Kudo (1947) and Duijn (1956) found dead and dying cells in infected tissues in fishes caused by *Glugea hertwigi* and allied species, and have reported that the host dies in advanced stages of the disease. While there are indications of some mortality caused by the infection, at the present preliminary state of study exact estimates are not possible. This problem needs a thorough investigation to determine the extent of mortality caused by these parasites.

The results show that in this instance a river estuarine system with greater river influences is a more important nursery area than a pond estuarine system with neritic conditions. The conclusions derived from the present study provide some basis for launching detailed and comprehensive future ecological studies of young fishes in other estuaries along the coast of Rhode Island, Narragansett Bay and its tributaries. These estuaries probably play an important role in maintaining the bay and coastal fisheries.

VII. SUMMARY

1. Shore seining of juvenile fishes was carried out in the lower Pettaquamscutt River and the lower Point Judith Pond from July 11 to October 20, 1962.
2. Based on the salinity "conflict" during a tidal cycle the lower Pettaquamscutt River is characterized as a "gradient zone" having a distinct salinity gradient while the lower Point Judith Pond (Figs. 1 and 2) is characterized as a "marine zone" which has near neritic conditions.
3. In a total of 41 species of young fishes 36 were recorded from the lower river and 24 from the lower pond. Fifteen species in the lower river and 11 in the lower pond appeared consistently; the rest appeared sporadically or were rare. Sixteen species recorded from the lower river and four from the lower pond were found only in those localities and not the other.
4. The abundance and diversity of various species of young fishes provided evidence that these two estuarine environments are heavily used as nursery grounds.
5. The abundance of young fishes fluctuated with the rise and decline in temperature. The greatest abundance of fishes was observed in mid-August while a few individuals of resident species remained in catches in late October.
6. No correlation between changes in salinity and in abundance of fishes was noticed. But anadromous, catadromous and certain other species (Table I) occurred only in the river estuary, where the salinity gradient extends from near neritic conditions to a fresh water environment.

7. There was no relationship observed between maximum abundance of fishes and maximum number of species appearing at any one time. Peaks in abundance of fishes were recorded in late July and August while peaks in species occurred in September.

8. The growth computations of certain selected species demonstrated that weekly intervals are too short to deduce satisfactory growth rates. Semimonthly or monthly intervals exhibited significant rates of growth. The estimation of an accurate rate of growth of *Menidia menidia* appearing in September and October was not possible because of an admixture of fish of uncertain age groups.

9. The abundance and diversity of taxonomic groups of food organisms was greater in the Pettaquamscutt River estuary.

10. Young *P. americanus* and *M. menidia* demonstrated change in preference for larger prey organisms with the change in size of the young fishes in both estuarine systems. Juvenile *B. tyrannus* consumed the same type of diet irrespective of increases in size.

11. Both juvenile and adult *M. menidia* depended largely on phytoplankton as food in the pond estuary. An apparent scarcity of carnivorous food motivated the larger fish to substitute phytoplankton as "forced diet."

12. The lower Pettaquamscutt River has greater river influences, and a higher profusion of benthic plant life than the lower Point Judith Pond. The environmental conditions observed in the lower river indicate that the former estuarine system is more favorable as a nursery ground for the young fishes.

13. While predators and most parasites did not demonstrate any noticeable harm to fish populations, infection by the sporozoan parasite *Glugea hertwigi*, was a possible cause of low catches of *P. americanus* particularly in the lower pond.

14. Based on the analyses of results, the parameters of abundance growth and food habits of selected species indicated the lower river estuary as the more favorable nursery ground.

VIII. ACKNOWLEDGEMENTS

The writer wishes to express his thanks to Dr. John T. Conover for his sincere interest, guidance and assistance in preparing the manuscript.

I am indebted to Dr. Charles J. Fish for the suggestion of this problem, for his continuous guidance and for providing gear for seining operations. Appreciation is also extended to Dr. Harry P. Jeffries and Dr. Donald J. Zinn for their helpful criticism. Thanks are also extended to Dr. Saul B. Saila and Thomas A. Gaucher for their help with the growth data and programming the statistical treatments. I am grateful to Dr. Sarah W. Richards of Yale, Dr. J. H. Fraser, Marine Laboratory, Aberdeen, Scotland, and Dr. Ronald L. Wigley, Fishery Biological Laboratory, Woods Hole for suggestions concerning the food habit of fishes, and Dr. Ross F. Nigrelli who kindly identified the sporozoan parasites of winter flounder. I am indebted also to Mrs. Thelma Ratisseau, of the Gulf Coast Research Laboratory, for typing the final manuscript and to Dr. Gordon Gunter, also of this Laboratory, for editorial criticisms.

IX. BIBLIOGRAPHY

Adolf, E. F. 1925. Some physiological distinctions between fresh and marine organisms. Biol. Bull., 48: 327-335.

Allen, K. B. 1935. The food and migration of the Perch (*Perca fluviatilis*) in Windermere. Jour. Anim. Ecol., 4: 246-273.

Berry, R. J. 1959. Critical growth studies of winter flounder *Pseudopleuronectes americanus* (Walbaum), in Rhode Island waters. M. S. dissertation, University of Rhode Island.

Bhattacharyya, R. N. 1957. The food and feeding habits of larval and post-larval herring in the Northern North Sea. Jour. Mar. Res. (Lond.), 3: 1-15.

Bigelow, H. B. and W. C. Schroeder. 1953. Fishes of the Gulf of Maine. Fish. Bull., U. S. Fish Wild. Serv., 53(74): 577 pp.

Brodski, K. A. and A. J. Jankovskaya. 1935. Contribution to the knowledge of food of the far eastern sardine. Bull. Far East. Br. Acad. Sci. U.S.S.R., No. 13: 102-114. (Translated by A. S. Loukashkin, Calif. Acad. Sci., San Fran.).

Brown, C. L. 1962. On the ecology of Aufwuchs of *Zostera marina* in Charlestown Pond, Rhode Island. M.S. dissertation, University of Rhode Island.

Conover, J. T. 1958. Seasonal growth of benthic marine plants as related to environmental factors in an estuary. Publ. Inst. Mar. Sci., (Univ. Texas), 5: 97-147.

Covill, R. W. 1959. Oceanography of Long Island Sound. Food and feeding habits of larvae and post-larvae of *Ammodytes americanus*. Bull. Bingham Oceanogr. Coll., 17(1): 125-146.

Crisp, D. J. 1926. The planktonic stages of the Cirripedia *Balanus balanoides* (L) and *Balanus balanus* (L) from North Temperate waters. Crustaceana, 3(3): 207-221.

Cupp, E. E. 1943. Marine plankton diatoms of the West Coast of North America. Bull. Scripps Inst. of Oceanogr., 5(1): 1-238.

Day, J. H. 1951. The ecology of the South African Estuaries. Transac. Roy. Soc. S. Africa., 33: 53-91.

Duijn, C. V., Jr. 1956. Diseases of Fishes. Water Life. Dorset House, Stamford St., London. 174 pp.

Emery, K. O., R. E. Stevenson and J. W. Hedgpeth. 1957. Estuaries and Lagoons. I. Physical and chemical characteristics. Treatise on Marine Ecology and Paleoecology, Vol. 1 Ecology. Geol. Soc. Amer. Memoir, 67: 673-750.

Fish, C. J. 1925. Seasonal distribution of the plankton of the Woods Hole region. Bull. U. S. Bur. Fish., 41: 91-179.

Goode, G. B. and W. O. Atwater. 1880. A History of the Menhaden with an Account of the Agricultural Uses of the Fish. Orange Judd Co., New York. 529 pp.

Greeley, J. R. 1939. Fishes and habitat conditions of the shore zones based upon July and August seining investigations. A biological survey of the salt waters of Long Island, 1938 pt. II, No. XV. Suppl 28th Ann. Rept. New York Conserv. Dept. :79-99.

Hartley, P. H. T. 1947. Food and feeding relationship in a community of fresh water fishes. Jour. Anim. Ecol., 17: 1-14.

Hatanaka, Masayoshi, Masaya Kosaka and Yuji Sato. 1956. Growth and food consumption in Plaice. Part I. *Limanda yokohamae* (Günther). Tohuku J. Agric. Res., 7: 157-162.

Herre, A. W. C. T. 1956. Marine fishes in fresh water. Science, 123(3206): 1035.

Herman, S. S. 1958. The planktonic fish eggs and larvae of Narragansett Bay. M.S. dissertation, University of Rhode Island.

Hiatt, R. W. and D. W. Strasburg. 1960. Ecological relationship of the fish fauna in coral reefs of the Marshall Islands. Ecol. Monogr., 30: 65-127.

Hicks, S. D. 1958. Distribution of Salinity in Pettaquamscutt River. Pettaquamscutt River Investigation, Div. Fish and Game and Narragansett Mar. Lab., 1-4.

Hildebrand, S. F. and W. C. Schroeder. 1927. Fishes of Chesapeake Bay. Bull. U. S. Bur. Fish., 43(1): 1-366.

Hile, Ralph. 1948. Standardization of methods of expressing lengths and weights of fish. Trans. Amer. Fish. Soc., 75: 157-164.

Hjort, Johan. 1926. Fluctuation in the year class of important food fishes. Jour. Cons. Int. Explor. Mer., 1: 5-39.

Horton, D. B. 1958. The occurrence and distribution of fish in Upper Pettaquamscutt River as related to certain chemical and physical variables. M.S. dissertation, University of Rhode Island.

Hubbs, C. L. and A. Perlmutter. 1942. Biometric comparison of several samples, with particular reference to social investigations. Amer. Nat., 76: 582-592.

Hubbs, C. L. and C. Hubbs. 1953. An improved graphical analysis and comparison of series of samples. Systematic Zool., 2: 49-57.

Huntsman, A. G. and M. I. Sparks. 1924. Limiting factors for animals. 3. Relative resistance to high temperature. Contr. Canada Biol., N.S. 2(6): 95-114.

Ivlev, V. S. 1945. Density and character of food distribution as factors determining the size of the ration in fishes. Zool. Zhurnal, 24(2): 112-125.

Jeffries, H. P. and T. J. Smayda. 1954. Late winter and early spring plankton populations in the Pettaquamscutt River, a brackish estuary in Rhode Island. Unpubl. Report, Narragansett Marine Laboratory.

———————. 1962. Salinity-space distribution of the estuarine copepod genus *Eurytemora*. Int. Rev. Hydrobiol., 47(2): 291-300.

Jordan, D. S. and B. W. Evermann. 1896-1900. The fishes of North and Middle America. Bull. U. S. Nat. Mus., No. 47. 1-4: 1-3313.

Kudo, R. R. 1947. Protozoology. 3rd Edition. Charles C. Thomas Publisher, Springfield, Illinois.

Kuntz, A. and L. Radcliffe. 1917. Notes on the embryology and larval development of twelve teleostean fishes. Bull. U. S. Bur. Fish., 35: 87-134.

McHugh, J. L., R. T. Oglesby, and A. L. Pacheco. 1959. Length, weight, and age composition of the menhaden catch in Virginia waters. Limm. Oceanogr., 4(2): 145-162.

McMaster, R. L. 1958. Distribution of bottom sediments. Pettaquamscutt River Investigation. Div. Fish and Game and Narr. Mar. Lab. Feb. 14, 1958, 3 pp.

Merriman, D. 1947. Notes on the mid-summer ichthyfauna of a Connecticut beach at different tide levels. Copeia, 4: 281-286.

Merriman, D. and R. C. Sclar. 1952. The pelagic fish eggs and larvae of Block Island Sound. Bull. Bingham Oceanogr. Coll., 13(3): 165-219.

Miner, Roy W. 1950. Field Book of Sea Shore Life. G. P. Putnam's Sons, New York. 888 pp.

Morris, R. W. 1955. Some considerations regarding the nutrition of marine fish larvae. Jour. int. Explor. Mer., 20: 255-265.

Pearcy, W. G. 1962. Ecology of young winter flounder in an estuary. Bull. Bingham Oceanogr. Coll., 18(1): 1-77.

Pearcy, W. G. and S. W. Richards. 1962. Distribution and ecology of fishes of Mystic River estuary, Conn. Ecology. 43(2): 248-259.

Pearse, A. S., H. J. Humm and G. W. Wharton. 1942. Ecology of sand beaches at Beaufort, North Carolina. Ecol. Monogr., 12: 135-190.

Peck, J. I. 1894. On the food of the menhaden. Bull. U. S. Fish Comm., (1893), 13(16): 113-126.

Perlmutter, Alfred. 1939. An ecological survey of young fish eggs identified from tow-net collections. A biological survey of the Salt Waters of Long Island, 1938, Pt. II, No. XV. Suppl. 28th Ann. Rept.: New York Conserv. Dept. 11-17.

——————. 1947. The black flounder and its fishery in New England and New York. Bull. Bingham Oceanogr. Coll., 9(2): 1-99.

Pettibone, M. H. 1963. Marine polychaete worms of the New England region. Smithsonian Inst., U. S. National Museum. Pub. No. 227, Part 1, 356 pp.

Prosser, C. L. and F. A. Brown, Jr. 1961. Comparative Animal Physiology. W. B. Saunders Company, Phila. 688 pp.

Richards, S. W. 1963. The demersal fish populations of Long Island Sound. Bull. Bingham Oceanogr. Coll., 18(2): 1-101.

Richardson, Harriet. 1905. A monograph of the isopods of North America. Bull. U. S. Nat. Mus., No. 54: 1-727.

Ricker, W. E. 1946. Production and utilization of fish populations. Ecol. Monogr., 16: 373-392.

Riley, G. A. 1937. The significance of Mississippi River drainage for biological conditions in the northern Gulf of Mexico: Jour. Mar. Res., 1(1): 60-74.

Rochford, D. J. 1951. Studies in Australian hydrography. I. Introductory and comparative features. Austr. J. Mar. Fresh. Res., 2(1): 1-116.

Rose, M. 1933. Faune de France, Copepodes pelagique. Paul Lechevalier, Paris. 372 pp.

Rounsefell, G. A. and W. E. Everhart. 1953. Fishery Science. Its methods and applications. John Wiley and Sons. New York. 444 pp.

Shaw, Evelyn. 1960. The development of schooling behavior in fishes. Physiol. Zool., 33: 79-86.

Shelbourne, J. E. 1953. The feeding habits of plaice post-larvae in the Southern Bight. J. Mar. Biol. Ass. U.K., 32: 149-159.

Shuster, C. N., Jr. 1959. A biological evaluation of the Delaware Bay estuary. Information Series, Publ. No. 3, University of Delaware Marine Lab. 1-77 pp.

Smith, H. M. 1898. The fishes found in the vicinity of Woods Hole. Bull. U. S. Fish. Comm., 1897. 17: 85-111.

Steven, G. A. 1933. The food consumed by Shags and Cormorants around the shores of Cornwall (England). J. Mar. Biol. Ass. U.K., 19: 277-292.

Stommel, H., and H. G. Farmer. 1953. Control of salinity in an estuary by transition. Jour. Mar. Res., 12(1): 13-20.

Tracy, H. C. 1906. A list of the fishes of Rhode Island. 36th Ann. Rept. Comm. of Inland Fisheries, Rhode Island: 38-99.

————. 1910. Annotated list of fishes known to inhabit the waters of Rhode Island. 40th Ann. Rept. Comm. of Inland Fisheries, Rhode Island: 35-176.

Verril, A. E. 1871. On the food and habits of some marine fishes. Amer. Nat., 5: 399.

Warfel, H. E. and D. Merriman. 1944. Studies on the marine resources of south New England. 1. An analysis of the fish population of the shore zone. Bull. Bingham Oceanogr. Coll., 9(2): 1-91.

Welsh, W. W., and C. M. Breder, Jr. 1924. Contribution to life histories of Sciaenidae of the eastern United States Coast. Bull. U. S. Bur. Fish., 39: 141-201.

Westman, J. R., and R. F. Nigrelli. 1955. Preliminary studies of menhaden and their mass mortalities in Long Island Sound and New Jersey waters. N. Y. Fish. and Game. Jour., 2: 142-153.

Wheatland, S. B. 1956. Oceanography of Long Island Sound, 1952-1953. VII. Pelagic fish eggs and larvae. Bingham Oceanogr. Coll., 15: 234-314.

Wilson, C. B. 1932. The copepods of the Woods Hole region. Bull. Nat. Mus., No. 158. 635 pp.

Gulf Research Reports

Volume 2 | Issue 2

January 1966

A Bibliography of Anomalies of Fishes, Supplement 1

C.E. Dawson

DOI: 10.18785/grr.0202.03

Recommended Citation

Dawson, C. 1966. A Bibliography of Anomalies of Fishes, Supplement 1. Gulf Research Reports 2 (2): 169-176.
Retrieved from http://aquila.usm.edu/gcr/vol2/iss2/3

A Bibliography Of Anomalies Of Fishes

Supplement 1

C. E. DAWSON

The original bibliography (Gulf Res. Repts. 1(6), 1964) has, reportedly, been of considerable value to workers interested in the teratology of fishes and other vertebrates. The present supplement is the first of a proposed series which will attempt to include all new and pertinent publications as well as those which have previously been overlooked. The overall usefullness of the bibliography should be enhanced by its maintenance on a relatively current basis. Supplements will be issued irregularly and will normally include 75 to 100 new citations.

In the interest of continuity, the original format and subject index headings have been retained. Supplemental citations will be serially numbered and prefixed by the letter "S".

Acknowledgement is made to colleagues who have provided reprints of their publications and to those who have called my attention to omissions in the original bibliography.

BIBLIOGRAPHY

S-1 Alperin, I. M. 1965. Recent records of pugheaded striped bass from New York. N. Y. Fish Game J. 12(1):114-115, 3 figs.

S-2 Amaoka, K. 1964. First record of sinistrality in *Poecilopsetta plinthus* (Jordan and Starks) a pleuronectid fish of Japan. Bull. Misaki Mar. biol. Inst., Kyoto Univ. 7:9-17, 3 figs.

S-3 Andreu, B. 1955. Un nuevo caso de hermafroditismo en *Sardina pilchardus* Walb. de la ria Vigo. Invest. pesq. 2:3-7.

S-4 Anon. 1953. Passage of fish over Bonneville Dam, Columbia River, Oregon and Washington, 1952. Ann. Rept. U. S. Army Eng., Portland, Oregon.

S-5 Anwand, K. 1961. Ein weiterer Fund eines Heringszwitters (*Clupea harengus* L.). [A further discovery of a herring hermaphrodite]. Z. Fisch. 10(4/5):383-386.

S-6 Barcellos, B. N. 1962. Anomalias do esqueleto da corvina. Cienc. e Cult. 14(2):111-113, 2 figs.

S-7 Barlow, G. W. 1963. Species structure of the gobiid fish *Gillichthys mirabilis* from coastal sloughs of the eastern Pacific. Pacif. Sci. 17(1):47-72, 13 figs.

S-8 Beardsley, A. J. and Horton, H. F. 1965. An ambicolored starry flounder from Yaquina Bay, Oregon. Calif. Fish Game 51(2): 126-128, fig.

S-9 Bell, G. R. 1961. Penetration of spines from a marine diatom into the gill tissue of lingcod (*Ophiodon elongatus*). Nature, Lond. 192(4799):279-280, 4 figs.

S-10 Berinkey, L. 1959. A *Lucioperca volgensis* with a deformed head from the River Danube. Opusc. zool. Inst. zoosyst. Univ. budapest 31:23-27, 2 figs.

S-11 Blackett, R. F. and Armstrong, R. H. 1965. Collection of two abnormal Dolly Varden: one with two dorsal fins, the other with incomplete pigmentation. Trans. Amer. Fish. Soc. 94(4): 408-409, fig.

S-12 Cadenat, J. 1960. Notes d'Ichtyologie ouest-africaine 32. - Sur un cas d'intersexualité chez un Requin de l'espèce *Centrophorus lusitanicus* Bocage et Capelle 1864. Bull. Inst. franc. Afr. noire (A) 22(4):1428-1430, 3 figs.

S-13 ——————— 1962. Notes d'Ichtyologie ouest-africaine 38. - Documents pour servir à la recherche des mécanismes de déplacement et de remplacement des dents chez les Requins. Bull. Inst. franc. Afr. noire(A) 24(2):551-579, 62 figs.

S-14 Cheek, R. P. 1965. Pugheadedness in an American shad. Trans. Amer. Fish. Soc. 94(1):97-98, fig.

S-15 Chhapgar, B. F. 1964. A monster of the spotted duck-billed ray, *Aetobatus narinari*. Copeia 1964(3):587-588, 2 figs.

S-16 Clark, E. 1964. Spinal deformity noted in a bull shark. Underw. Nat. 2(3):25-28.

S-17 Datta Gupta, A. K. and Tilak, R. 1962. A note on the deformity of *Heteropneustes fossilis* Bloch (Heteropneustidae: Siluroidea). Zool. Polon. 12(3):305-398, 2 figs.

S-18 Davidson, F. A. 1934. The homing instinct and age at maturity of pink salmon (*Oncorhynchus gorbuscha*). Bull. U. S. Bur. Fish. 48(15):27-39.

S-19 DeLacy, A. C. and Batts, B. S. 1963. A search for racial characteristics in the Columbia River smelt. Contr. Sch. Fish. Univ. Wash. 147:30-32.

S-20 ——————— and Dryfoos, R. L. 1965. The longfin smelt in Lake Washington. Contr. Sch. Fish. Univ. Wash. 184:37.

S-21 Desbrosses, P. 1931. Poissons de Chalut. Traumatismes de la bouche chez la dorade commune. Les problemes qu'ils posent, concernant la biologie de cette espece. Rev. Trav. Off. Pech. marit. 4(1):183-196.

S-22 Du Buit, M. H. 1964. Une raie anormale trouvée a Concarneau. Bull. Mus. Hist. nat., Paris 36(2):180-184, 3 figs.

S-23 Dutt, S. 1959. Biometric studies on *Sardinella* spp. off Waltair Coast. Proc. 1st All-India Congr. Zool. 1959(2):286-298, fig.

S-24 ——————— 1961. Biometric studies on *Sardinella* spp. off Waltair Coast. 2. *Sardinella gibbosa* Blkr. J. zool. Soc. India 13(1):78-89.

S-25 Eigenmann, C. H. 1894. On the viviparous fishes of the Pacific coast of North America. Bull. U. S. Fish. Comm. 12:371-478.

S-26 Feider, Z., *et al.* 1959. Une rare anomalie de la branchie chez le saurel de la Mer Noire (*Trachurus trachurus mediterraneus*). Lucrar. Stat. zool. mar. Agigeo (Vol. festiv) 1959:147-149, 2 pls.

S-27 Fitch, J. E. 1963. A review of the fishes of the genus *Pleuronichthys*. Contr. Sci. Los Angeles Cty. Mus. 76:1-33.

S-28 Follett, W. I., McCormick, R. B., and Best, E. A. 1960. First records of sinistrality in *Microstomus pacificus* (Lockington) and *Glyptocephalus zachirus* Lockington, pleuronectid fishes of western North America, with meristic data. Copeia 1960(2): 112-119, 2 figs.

S-29 Fry, D. H., Jr. 1961. Some problems in the marking of salmonids. Bull. Pacif. Mar. Fish. Comm. 5:78-83.

S-30 Fuller, A. S. 1961. An intra-pericardial hepatic intrusion in the common dogfish. Nature, Lond. 192(4799):280, fig.

S-31 Gabriel, M. L. 1944. Factors affecting the number and form of vertebrae in *Fundulus heteroclitus*. J. exp. Zool. 95(1):105-147.

S-32 Geus, A. 1961. Uber eine siamesische Zwillingsbildung bei einem Mänchen *Lebistes reticulatus* Peters. Aquar.-u. Terra. Z. 14: 217-219, 5 figs.

S-33 Godet, R. 1961. Un cas d'hermaphrodisme chez le Protoptère (Poisson Dipneuste). Ann. Fac. Sci. Univ. Dakar 6:145-149, 2 pls., fig.

S-34 Goriunova, A. I. 1961. Deformatsiia chesun u serebrianogo karasia. (The deformation of scales in silver crucian). Vop. Ikhtiol. 1(18):52-58.

S-35 Honma, Y. 1964. Notes on the specimens of halfbeaks, *Hemirhamphus sajori* (T. & S.), bound their heads or trunks with rubber bands. Collect. & Breed. 26(2):1-3, fig.

S-36 ________ 1964. Notes on the encephalocele (hernia cerebri) found in a young salmonid fish, the koayu, *Plecoglossus altivelis* Temminck et Schlegel. Bull. Jap. Soc. sci. Fish. 30(11):912-917, pl., fig.

S-37 ________ and Duyvené de Wit, J. J. 1961. Teratologic observations in rhodine species and hybrids (Cyprinidae). 1. Three specimens with abnormal heads. Annot. zool. jap. 34: 153-158.

S-38 ________ and Tamura, E. 1964. Notes on the deformity of dorsal fin in a specimen of Japanese char, the Nikko-iwana, *Salvelinus leucomaenis pluvius.* Collect. & Breed. 26(12):368-369, 2 figs.

S-39 Ingalls, T. H. and Murakami, U. 1962. Cyclopia, ectromelia, and other monstrosities in zebra fish. Arch. Environ. Health 5: 114-121.

S-40 Isaacson, P. A. 1965. Pugheadedness in the black perch, *Embiotoca jacksoni.* Trans. Amer. Fish. Soc. 94(1):98.

S-41 Kändler, R. 1932. Unsicherheiten bein Bestimmung der Wirbelzahl infolge Verwachsungserscheinungen. J. Cons. 7(3):373-385, 7 figs.

S-42 Klausewitz, W. 1961. Ein bemerkenswerter Fall von Albinismus bei *Acanthopthalmus semicinctus.* Aquar.-u. Terrar. Z. 14: 9-10, fig.

S-43 Kozikowska, Z. 1961. Interesting deviations from usual form in the lateral line of the carp (*Cyprinus carpio* L.) from the breeding ponds near Radziadz in Silesia. Zool. Polon. 10(4): 333-336, illus.

S-44 Krupauer, V. 1961. Take u kapra se muzeme setkat s hermafroditismem. (We also find hermaphroditism in carp). Csl. Rybarst. 9:134-135.

S-45 Lamont, J. M. 1961. Fish with rubber bands. Scot. Fish. Bull. 15:17-18.

S-46 Lawler, G. H. 1960. A mutant pike, *Esox lucius.* J. Fish. Res. Bd. Can. 17(5):647-654.

S-47 ________ 1964. A northern pike, *Esox lucius,* with an accessory fin. J. Fish. Res. Bd. Can. 21(6):1547, fig.

S-48 ________ 1965. Fin anomalies in the white sucker, *Catostomus commersoni,* population in Heming Lake, Manitoba. J. Fish. Res. Bd. Can. 22(1):219-220, fig.

S-49 Lea, R. N. 1965. A lahontan redside, *Richardsonius egregius* (Girard), lacking pelvic fins. Calif. Fish Game 51(4):300.

S-50 Leonards, L. 1963. Possible albino adult chinook salmon observed. Res. Briefs Ore. Fish Comm. 9(1):67.

S-51 Lewis, D. E. 1961. Sockeye salmon, *Oncorhynchus nerka,* without a dorsal fin. Copeia 1961(1):116-117, 2 figs.

S-52 McCrimmon, H. R. and Bidgood, B. 1965. Abnormal vertebrae in the rainbow trout with particular reference to electrofishing. Trans. Amer. Fish. Soc. 94(1):84-88, 3 figs.

S-53 Meinken, H. 1961. Nochmals "Ein albinotischen *Clarias*". Aquar.-u. Terrar. Z. 14:329-330, fig.

S-54 Miller, G. C. 1964. An aberrant green sturgeon from the lower Columbia River. Res. Briefs Ore. Fish Comm. 10(1):70-72, 2 figs.

S-55 Morgan, A. R. and Gerlach, A. R. 1950. Striped bass studies on Coos Bay in 1949 and 1950. Contr. Fish Comm. Ore. 14:1-31.

S-56 Neill, W. T. 1950. A channel catfish with a forked barbel. Copeia 1950(4):317.

S-57 Ochiai, A. 1964. An aberrant frogfish from Japan. Bull. Misaki Mar. biol. Inst. Kyoto Univ. 5:39-41, fig.

S-58 Olshanskaya, O. L. 1960. Urodstva u eniseiskoi sterliadi. (Abnormalities in Yenisey sterlet). Vop. Ikhtiol. 16:191-195, 2 figs.

S-59 O'Riordan, C. E. 1961. A variation of the flounder *Platichthys flessus* (L.) from Co. Wexford. Irish Nat. J. 13(9):213-214.

S-60 Orska, J. 1962. Anomalies in the vertebral columns of the pike (*Esox lucius* L.). Acta biol. cracov. Zool. 5(2):327-345, illus.

S-61 Paiva, M. P. 1961. Um caso de ausencia da nadadeira adiposa em *Pygocentrus nattereri* Kner, 1860. Bol. Soc. Cear. Agron. 2:45-46, fig.

S-62 —————— 1965. On a pelvicless specimen of *Pygocentrus piraya* (Cuvier, 1820) from Jaguaribe River basin, Brazil. Copeia 1965(1):110.

S-63 Raja, B. T. A. 1963. An instance of hermaphroditism in the Indian oil sardine, *Sardinella longiceps* (Cuv. & Val.). J. Mar. biol. Ass. India 5(1):148-150, fig.

S-64 Raju, G. 1960. A case of hermaphroditism and some other gonadal abnormalities in the skipjack *Katsuwonus pelamis* (Linnaeus). J. Mar. biol. Ass. India 2(1):95-102, 5 figs.

S-65 Reed, R. J. 1954. Hermaphroditism in the rosyface shiner, *Notropis rubellus*. Copeia 1954(4):293-294.

S-66 Regan, J. D. 1961. Melanism in the poeciliid fish, *Gambusia affinis* (Baird and Girard). Amer. Midl. Nat. 65(1):139-143, 2 figs.

S-67 Reichenback - Klinke, H. H. 1961. Ein Nase - Nerfling - Bastard [*Chondrostoma nasus* (L.) x *Idus idus* (L.)] mit abnorm verlangerten Flossen. Allg. FischZtg. 86(5):151-152.

S-68 Rich, W. H. and Holmes, H. B. 1929. Experiments in marking young chinook salmon in the Columbia River, 1916 to 1927. Bull. U. S. Bur. Fish. 44:215-264.

S-69 Rietze, H. L. 1954. Naturally missing fins from chum salmon. Res. Briefs Ore. Fish Comm. 5(1):26.

S-70 Sachs, W. B. 1961. Ein albinotischer *Clarias*. Aquar.-u. Terrar. Z. 14:268-269, fig.

S-71 Saemundsson, B. 1909. Oversigt over Islands fiske. Skr. Komm. Havunders 5:1-140.

S-72 Salekhova, L. P. 1961. Hermaphroditism of *Diplodus annularis* (L.). (in Russian). Trav. Sebast. biol. Sta. 14:257-268, 10 figs.

S-73 Sathyanesan, A. G. 1962. On the abnormal dorsal fin of the teleost *Labeo calbasu* (Ham.). Sci. & Cult. 28(12):588-589, illus.

S-74 Schwartz, F. J. 1965. A pugheaded menhaden from Chesapeake Bay. Underw. Nat. 3(1):22-44, 3 figs.

S-75 Shchupakov, L. G. and Kharchenko, L. N. 1960. Anomalies among interspecific hybrids of whitefishes produced in Ural commercial fish farms. (in Russian). *in* Distant Hybridization of Plants and Animals, pp. 520-531.

S-76 Shulyak, G. S. 1961. Cases of atypical structure of the intestine in carp. (Russian with English summary). Dopov. Akad. Nauk. ukr. RSR 3:384-386, 3 figs.

S-77 Singh, T. P. and Sathyanesan, A. G. 1961. An instance of hermaphroditism in the catfish *Mystus vittatus* (Bloch). Curr. Sci. 30:302-303, 2 figs.

S-78 Sommani, E. 1962. Interessante caso di mostruosita in esemplare di tinca (*Tinca tinca* L.). Boll. Pesca Piscic. Idrobiol. 15(2): 109-193.

S-79 Steffens, W. 1961. Flossenschadingungen beim Hecht (*Esox lucius*). Biol. Zbl. 80(1):79-84.

S-80 Templeman, W. 1965. Some abnormalities in skates (*Raja*) of the Newfoundland area. J. Fish. Res. Bd. Can. 22(1):237-238, 4 figs.

S-81 Tester, A. L. 1949. Populations of herring along the west coast of Vancouver Island on the basis of mean vertebral number, with a critique of the method. J. Fish. Res. Bd. Can. 7(7): 403-420.

S-82 Tschvertner, U. 1956. Untersuchungen ueber den einfluss einiger Milienfaktoren auf die Entwicklung des Hechtes (*Esox lucius* L.). Arch. Hydrobiol. 24(3):123-152.

S-83 Uchida, R. N. 1961. Hermaphrodite skipjack. Pacif. Sci. 15:294-296, 3 figs.

S-84 Vastesaeger, M., *et al.* 1961. L'atherosclerose spontanée du thon rouge (*Thynnus thynnus* L.). Bull. Cent. Etud. Rech. sci., Biarritz 3:449-455, 4 figs.

S-85 Walker, J. M. and Taylor, H. L. 1965. A brook trout with no anal fin. Progr. Fish Cult. 27(4):233, fig.

S-86 Ward, J. W. and Dodds, R. P., Jr. 1965. Observations upon a natural population of normal, hemicaudate, and decaudate goldfish, *Carassius auratus.* J. Miss. Acad. Sci. 11:191-195, fig.

S-87 White, J. C., Jr. and Hoss, D. E. 1964. Another record of incomplete ambicoloration in the summer flounder, *Paralichthys dentatus.* Chesapeake Sci. 5(3):151-152, fig.

S-88 Williamson, H. C. 1909. Abnormal skate (*Raia circularis* and *Raia clavata*). Rep. Fish. Bd. Scot. 28(3):64, 3 figs.

S-89 Wunder, W. 1956. Leistungs prüfungsversuche beim Karpfen 1955. Ergebnisse aus bayerischen Teichwirtschaften. Arch. FischWiss. 7(1):17-30.

S-90 ———————— 1960. Erbliche Flossenfelder beim Karpfen und ihr Einfluss auf die Wachstrumsleistung. Arch. FischWiss. 11: 106-119, 14 figs.

S-91 ———————— 1961. Formveranderung der Schwimmblase des Karpfens bei Wirbelsaulenverkrummung. Allg. FischZgt. 86(8): 236-238.

TAXONOMIC INDEX

SUBJECT INDEX

Gulf Research Reports

Volume 2 | Issue 2

January 1966

Studies of Annual Abundance of Postlarval Penaeid Shrimp in the Estuarine Waters of Mississippi, As Related to Subsequent Commercial Catches

J.Y. Christmas
Gulf Coast Research Laboratory

Gordon Gunter
Gulf Coast Research Laboratory

Patricia Musgrave
Gulf Coast Research Laboratory

DOI: 10.18785/grr.0202.04

Recommended Citation

Christmas, J., G. Gunter and P. Musgrave. 1966. Studies of Annual Abundance of Postlarval Penaeid Shrimp in the Estuarine Waters of Mississippi, As Related to Subsequent Commercial Catches. Gulf Research Reports 2 (2): 177-212.
Retrieved from http://aquila.usm.edu/gcr/vol2/iss2/4

STUDIES OF ANNUAL ABUNDANCE OF POSTLARVAL PENAEID SHRIMP IN THE ESTUARINE WATERS OF MISSISSIPPI, AS RELATED TO SUBSEQUENT COMMERCIAL CATCHES[1]

by

J. Y. Christmas, Gordon Gunter and Patricia Musgrave

Gulf Coast Research Laboratory,

Ocean Springs, Mississippi

THE PROBLEM

During the past fifteen years the landings of commercial shrimp at Mississippi ports have varied by a factor of three and even from one year to the next the catch has varied by a factor of 2.5. These facts are shown in table 1. The dollar values of the landings have varied somewhat less, about 2.1 at the most, as shown in the same table, because as fewer shrimp are caught the price goes up and vice versa. Thus the law of supply and demand causes shrimp prices to vary less than total landings.

The above figures refer to Mississippi landings from all waters of the Gulf Coast, chiefly Louisiana, with lesser amounts from Mississippi, Alabama and a very little from Florida and Texas.

The commercial shrimp catch figures for Mississippi Sound have only been available since 1956. The annual catches are shown in table 2. This includes all three species of commercial shrimp. The area includes a small part of Mississippi Sound that lies in Alabama, and the figures do not include the outside waters of Mississippi. Therefore, the figures do not represent the total annual catches from State waters. Table 2 shows that Mississippi production has varied by a factor greater than three since 1956.

Not all shrimp taken in Mississippi Sound are landed in the State. Insofar as some shrimp caught within the State are carried out of it and some caught outside of the State are brought into it, it is most probable that the Mississippi Sound production plus the shrimp taken in the Gulf off Mississippi make up about half of the State landings. Between 1956 and 1964 the annual catch in the Sound varied from an amount equivalent to 27 to 46 per cent of the State landings, the average being 36 per cent per year.

The initial catches when the shrimp season opens are made mostly in the Sound and it is a matter of considerable economic importance to the local industry to know what the abundance of the commercial population will be from year to year. Additionally, many shrimp taken in the open Gulf off the Mississippi coast come from the Sound originally.

Several workers and several lines of evidence have shown that the

[1] Supported by United States Bureau of Commercial Fisheries contracts 14-17-0002-43, 14-17-0002-81-A and 14-17-0002-101 with the Gulf Coast Research Laboratory, which extended from 1 November 1962 to 31 October 1964.

Table 1. Mississippi Landings of Commercial Shrimp. Heads on Weight

	Thousand pounds	Thousand dollars
1950	9,460	2,071
1951	7,475	1,470
1952	6,800	1,611
1953	8,517	2,301
1954	8,261	1,534
1955	13,617	2,504
1956	10,912	2,753
1957	9,569	2,617
1958	6,476	2,377
1959	11,319	2,345
1960	11,031	2,899
1961	4,408	1,281
1962	6,104	2,220
1963	9,375	2,484
1964	4,034	1,805

Table 2. Mississippi Sound (areas 011.1 and 012.1) total catch, heads on weight in thousand pounds (Conversion from Gulf Coast Shrimp Data, U. S. Bureau of Commercial Fisheries).

1956	2991
1957	3194
1958	2504
1959	5167
1960	4234
1961	1584
1962	2147
1963	2225
1964	2295

shrimp life cycle is very short, probably about 15 to 16 months, for the very small fraction reaching the largest adult size. Additionally, a great deal of commercial fishing is carried out upon sub-adult populations within the bays and shallow Gulf. In fact most shrimp that are caught have never spawned. These shrimp grow up within one warm season and they are derived from larvae which make their way to inside waters from the off-shore spawning areas. Thus, it has been surmised for a long time that prediction of at least the relative abundance of the future shrimp could be deduced from studies of the numbers of young or juvenile shrimp in the bays right after they have completed their larval immigration.

The first work on this problem was carried out by Baxter (1962) at the Galveston Laboratory of the Bureau of Commercial Fisheries. He sampled one area at the entrance of Bolivar Pass, leading into Galveston Bay, with a beam trawl.

Work at the Gulf Coast Research Laboratory in Mississippi Sound was carried out under contract with the Bureau of Commercial Fisheries, and was initiated on 1 November 1962. The contract was terminated on 31 October 1964, although the work has been carried out on a reduced scale since that time. The present report covers the period of the contract.

The Gear Used

A small beam trawl of such size that it could be dragged by one man was used in this program. In part this gear was used because it would give data comparable to what had been collected before by Baxter and in part because it was quite suitable for sampling small organisms in shallow waters. This gear was figured and described by Renfro (1963). It was also described by Baxter (1963) in the following words:

"Samples are collected semiweekly using a hand-drawn beam trawl fitted with a plankton net at the cod end (Renfro, In press). The net is 5 feet wide (along both cork and lead lines) by 2 1/3 feet long. The wings are made of nylon material having 50 holes per square centimeter. The body tapers to a canvas cylinder about 5 inches in diameter and 8 inches long. A 12-in, #1-mesh plankton net with a removable bucket is fitted over the collar. The plankton net is secured by a snap and ring arrangement.

"Around both collar and plankton net is fitted a 2 1/4-foot section of light canvas which acts as chafing gear. A 7-foot piece of 3/16-inch stainless steel cable, onto which are threaded additional lead weights, serves as the net's lead line. The ends of the cable are attached by means of swivels to the ends of a 6-foot length of 11/16-inch stainless steel pipe which constitutes the beam. To the cork line are threaded five 2 3/4-inch sponge floats. The cork line ends are tied directly to the beam, 8 inches from either end. A 15-foot length of nylon parachute cord serves as the bridle line. The effective opening of the net unit is approximately 5.8 square feet."

The net used in Mississippi differed from the one described by Baxter by two minor modifications. (1) The canvas section around the plankton net and collar was made longer than the Galveston net to prevent wear on the bag of the plankton net. (2) A short line was attached to a bight of the bridle to allow walking outside of the path of the net instead of in

front of it. A strap loop was attached to the end of the line for easier handling.

Sampling Procedure

The following description of the method of sampling is given by Baxter:

"The sample is taken in the following manner. A 6-foot stake (½-inch galvanized tubing) with 150 feet of nylon parachute cord attached, is driven into the ground at the shoreline. The cord is payed out and stretched taut parallel to the water line. Using the cord as a constant radius, the operator pulls the net assembly along the bottom in a half circle. This method is duplicated each time so that standard tows are obtained. The depth of tow varies from 0 to 4 feet depending on tidal conditions and roughness of the water. The effective length of each tow is about 470 feet, the volume of water sampled is 2,477 cubic feet, and the bottom area traversed is 1,958 square feet."

In collecting the Mississippi samples the operators did not walk in in front of the net because it was thought this would unduly disturb the bottom. Thus, the man pulling the net walked outside of the smaller semicircle the net traversed around the stake. At one station, number 31, the water was too deep for wading and the net was pulled for a fixed distance along the shore. For various reasons this station was not visited regularly.

After the tow was made the net was washed to remove as much mud and sand as possible. The net contents often included large amounts of vegetable debris. The washing usually reduced the total sample to an amount which could be placed in a gallon jar. A solution of 40% formaldehyde was added to this jar.

The water temperature, to the nearest tenth of a degree C., was taken by the simple process of holding the thermometer in the water. A water sample at the bottom was taken in a citrate bottle and returned to the laboratory where hydrometers were used to determine salinities. Tidal conditions, wind direction and estimated velocity, state of the sea and sky and general observations of turbidity of the water were recorded.

Stations

The location of all stations is given in table 3. These locations are shown on plate 1, which is a map of the Mississippi Sound area. A short description of each station area may be given as follows:

STATION 1 — Davis Bay

Located along East Beach of Ocean Springs, this station has a fairly firm sand bottom along its marsh-lined beach changing to a soft mud bottom in deeper water. A drainage ditch empties into the bay at the eastern edge of the station area.

STATION 4 — East End of Deer Island

Located along the western end and southern side of Little Deer Island (Fawn Island), the bottom of this station varies from firm sand to soft mud with a sand-mud combination being the usual case. Along the western edge of the station area is a small marsh bed. Extensive grass beds (***Ruppia maritima***) and an abundance of hermit crabs in the station area are seasonal occurrences.

STATION 8 — West End of Horn Island, North Shore

This station has a sand beach as the southern border and a clean, firm sand bottom. Shifting sand, causing increased depth, required shifting of this station location back and forth over an area within about a mile of the end of the island.

STATION 11 — Belle Fontaine Beach, East at Jetty

The sand bottom of this station is usually covered with a ½-6 inch layer of soft mud. The water in the area is generally quite muddy with a large amount of debris which makes a dark swash mark on the clean white sand beach. Dredging operations at this station changed the bottom so that the station location was moved east approximately one mile in August 1963.

STATION 13 — Horn Island, Horseshoe

The firm sand bottom of this station is spattered with occasional small grass patches. The sand beach border and the depth of water vary frequently.

STATION 14 — Round Island

This station has a sand beach with a clean, hard sand bottom.

STATION 15 — Pascagoula River, Island off Spanish Point

This station has a sand beach with its bottom varying from soft mud to firm sand. Spoil in the station area from the dredging of the Pascagoula Channel caused the abandonment of this station in October 1963.

STATION 18 — Henderson Point, East at Jetty

Sand beach with firm, clean sand bottom.

STATION 19 — Bayou Caddy, East of Entrance

Bordered by a sand beach and sea wall, this station has a fairly firm mud-sand bottom with shells along the sea wall. Usually there is much trash washed into the station area.

STATION 20 — Cedar Point, Bay of St. Louis

The haul here is made around a large marsh bed. The bottom varies from firm mud-sand to soft mud with occasional grass patches.

STATION 21 — Shell Beach, Bay St. Louis (Oblate Fathers Property)

The beach at this station is composed primarily of shells. The bottom is relatively soft mixture of red clay, sand, pebbles, and shells.

STATION 22 — East End of Horn Island

Sand beach with firm, clean sand bottom.

STATION 23 — Gaston Point, Gulfport Beach

Sand beach with firm sand bottom. Occasionally mud-sand bottom.

STATION 24 — North Point, Cat Island

Sand beach and firm sand bottom with approximately half of sampling area covered with grass beds.

STATION 25 — West End of Ship Island

Sand beach with firm, clean sand bottom.

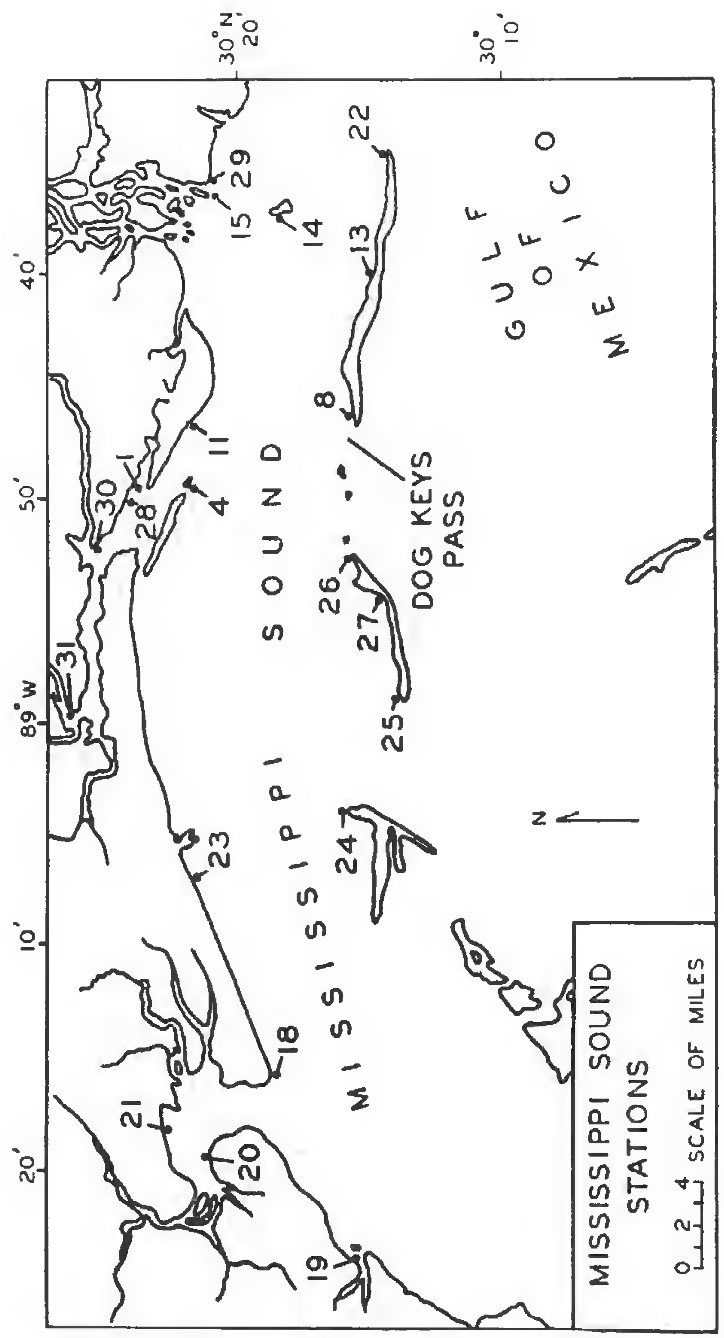


Figure 1. — Stations used for sampling penaeid postlarvae in Mississippi Sound and adjacent waters.

Table 3. Location of Stations Shrimp Postlarval Studies

Sta. No.	Latitude	Longitude	
1	30° 23' 36" N	88° 48' 31" W	Davis Bay
4	30° 21' 25" N	88° 48' 34" W	Deer Island, East End
8	30° 14' 42" N	88° 46' 11" W	Deer Island, West End
11	30° 20' 31" N	88° 45' 47" W	Belle Fontaine Beach, East at Jetty
13	30° 14' 03" N	88° 39' 13" W	Horn Island, Horseshoe
14	30° 17' 58" N	88° 35' 28" W	Round Island
15	30° 20' 12" N	88° 34' 07" W	Pascagoula River, Island off Spanish Point
18	30° 18' 10" N	89° 17' 25" W	Henderson Point, East at Jetty
19	30° 15' 35" N	89° 25' 27" W	Bayou Caddy, East of Entrance
20	30° 20' 35" N	89° 20' 48" W	Bay of St. Louis, Cedar Point
21	30° 22' 30" N	89° 19' 28" W	Bay of St. Louis, Shell Beach
22	30° 13' 21" N	88° 33' 32" W	Horn Island, East End
23	30° 21' 22" N	89° 06' 48" W	Gaston Point, Gulfport Beach
24	30° 15' 06" N	89° 03' 36" W	Cat Island, North Point
25	30° 12' 40" N	88° 58' 54" W	Ship Island, West End
26	30° 14' 42" N	88° 52' 25" W	Ship Island, East End
27	30° 14' 06" N	88° 53' 36" W	Ship Island, East Point of Lagoon Entrance
28	30° 23' 54" N	88° 48' 36" W	Ocean Springs East Beach, West End at Bridge
29	30° 20' 36" N	88° 33' 45" W	Pascagoula East River, East Point at Mouth
30	30° 25' 21" N	88° 50' 54" W	Biloxi Bay North Shore, East Point of Fort Bayou Entrance
31	30° 26' 12" N	88° 59' 42" W	Tchouticabouffa River, East Shore at Confluence with Biloxi River

Table 4. Number of Monthly Visits to Each Station

	1962		1963												1964									
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mr.	Apr.	Ma.	Jun.	Jul.	Au.	Sep.	Oct.
Station 1	1	4	4	3	4	4	5	4	5	4	4	5	4	2	4	4	4	5	4	4	5	3	4	4
Station 4	3	4	5	4	4	4	5	4	4	4	4	5	4	3	5	4	4	5	4	4	4	4	4	2
Station 8	1		4	4	4	4	4	3	5	4	3	5	4	4	2	2	4	4	4	4	5	4	3	
Station 11		1	4	3	4	4	5	4	5	4	4	5	4	3	2	4	4	5	4	4	5	4	4	4
Station 13			4	4	4	4	5	3	5	4	4	5	4	4	4	4	4	4	4	4	5	4	4	1
Station 14			3	4	3	3	5	3	5	4	3	5	4	3				1						
Station 15			2	2	3	4	5	2	5	3	3													
Station 18			1	4	4	4	5	4	5	4	4	5	4	3	1	3	4	5	4	4	5	4	5	4
Station 19			1	4	4	4	5	4	5	4	3	4	4	3	2	3	4	5	4	4	5	4	4	3
Station 20				4	4	4	5	4	5	4	3	5	5	3	3	3	4	5	4	4	5	4	5	4
Station 21				1	4	4	5	4	5	4	4	5	4	3										
Station 22				3	4	3	4	3	5	2	3	3	4	4	1			3	4	4	5	4	3	1
Station 23				1	4	4	5	4	5	4	4	5	4	3	3	4	4	5	4	4	5	4	5	4
Station 24					4	3	4	3	4	2	2	5	4	2				2	3	3	3	2	2	
Station 25					4	3	5	3	4	1	2	4	4	2				2	3	4	4	2	2	
Station 26					4	3	5	3	4	3	4	5	4	2				2	3	4	4	4	3	
Station 27						2	5	3	5	2	4	5	4	2		1		2	3	4	4	3	3	
Station 28							5	4	5	4	4	5	4	2										
Station 29												2	4			1	4	5	4	4	5	4	5	4
Station 30												1				4	4	4	4	2	4	4	3	2
Station 31															1	4	4	4		1	4	2		

STATION 26 — East End of Ship Island

Sand beach with clean sand bottom.

STATION 27 — Ship Island Lagoon

Sand beach and firm sand bottom with grass beds covering the sampling area at times. Grass beds were occasionally covered by shifting sand.

STATION 28 — Ocean Springs East Beach, Biloxi Bay

Sand beach with fairly firm sand-mud in close to shore and a soft mud bottom in deeper water.

STATION 29 — Entrance to Pascagoula Small Craft Harbor, southern side

Sand and shell beach with sand and shell mixture forming a crust over the soft mud bottom. One medium size grass patch was present in sampling area. This was established when station 15, across the Pascagoula river, was abandoned.

STATION 30 — Fort Bayou Entrance, Eastern Side

The bottom type is a mixture of sand, clay, and mud with occasional grass patches. The sampling area encompasses a large intertidal marsh bed.

STATION 31 — Lopez Point, Tchouticabouffa River

Grass-lined shore with a bottom of sand and mud. There is usually much detritus in the sampling area.

The original plans for visiting stations called upon the workers to begin on Wednesday of each week and complete a standard haul at each of the stations listed in table 3 as soon as weather and physical conditions permitted. Stations not sampled in 3 days were omitted until the following week. By and large this program was carried out. Table 4 gives the numbers of times each station was visited each month during the period of the project.

Laboratory Procedures

As stated above 40% formalin was added to the samples in the field, but the total solution was actually much less after the net was washed into the jar and water content of the plant debris was taken into consideration. Usually within three days after collection, penaeid larvae in the samples were removed and placed in buffered 5% formalin. Occasionally, when work fell behind for one reason or another, some of the field samples were not examined until two weeks had passed.

All penaeid postlarvae and juveniles were removed from each sample. The samples were examined in large shallow pans over and over until no further penaeids were found. The small shrimp were separated into species, were counted and stored in small cotton-stoppered vials placed inside of larger containers. The specimens for each station were kept separately by months and by sample numbers. The remainder of the samples have been kept, for these contain fish larvae and many other organisms. In some instances certain of the fishes have been removed and used for other studies.

Identification of the small shrimp caused some problems in the beginning because the published keys are not fully satisfactory and must be used with caution. The workers found, however, that by following the

postlarvae up to easily recognized stages that they could differentiate the commercial post larvae quickly and with surety. On occasion other shrimp workers conferred with the staff on identification and checks of identification accuracy were made by different workers going through the same samples and separating the species. Correspondence was quite high and the workers quickly became adept and confident at their identifications. Needless to say the specimen material is being kept and is subject to further check at any time.

Figures two, three, four, and five show specific and seasonal differences in the three species of postlarvae included in this study. The figures were drawn by Mr. Douglas Farrell from preserved specimens collected and identified by project workers. All postlarvae were in about the same stage of development and the scale is the same for all four illustrations. Difference in the size of brown shrimp postlarvae in the spring and summer is evident in figures two and three. During the early part of the year there was no difficulty in distinguishing the brown shrimp postlarvae, because of their greater size. However, during the summer the postlarval brown shrimp did not vary a great deal in size from the other two species. Wide intraspecific variation of characteristics was observed. Identification was most difficult when postlarvae of all three species were on the nursery grounds at the same time.

THE ENVIRONMENT

Intertidal Bottom and Tides

In Mississippi Sound and adjacent waters many environmental factors vary from area to area and from time to time. Along the barrier islands, intertidal areas are almost entirely in sand. Fairly steep berms, bare of vegetation, form along the mean high tide level. Passes between the islands are wide and relatively shallow. Deeper passes are found at the west end of each of the islands.

Extensive grass beds appear along the Sound side. The bottom is always bare near the ends of the islands. Large masses of sand are sometimes shifted, changing the contour of the shoreline and bottom.

On the mainland and inshore islands, intertidal areas are more varied. Over one-third of the Mississippi Sound coastline in Mississippi has been "improved". Wide sand beaches have been built in front of sea walls by pumping material in from the shallow waters off shore. Clay and silt soon leach out, leaving a clean sand surface. Constant maintenance prevents the growth of plants which, initially at least, start to cover recently filled areas. The near shore bottom along these beaches varies from sand to sandy mud. The natural sand beach at Belle Fontaine is several miles long. The bottom along this beach is usually softer than that along the artificial beaches.

Around the bays, distributaries and bayous there is usually a marsh grass border of variable width. The bottom is usually soft mud which, in many places, will not support a man walking any distance off shore. During the two years of this study we have observed increased deposit of sand in several areas. When some stations were established the individual pulling the net usually sank at least knee deep at the outer edge of the haul, making it very difficult to complete the sample. At several stations the bottom became gradually firmer and by the end of the sampling period little diffi-

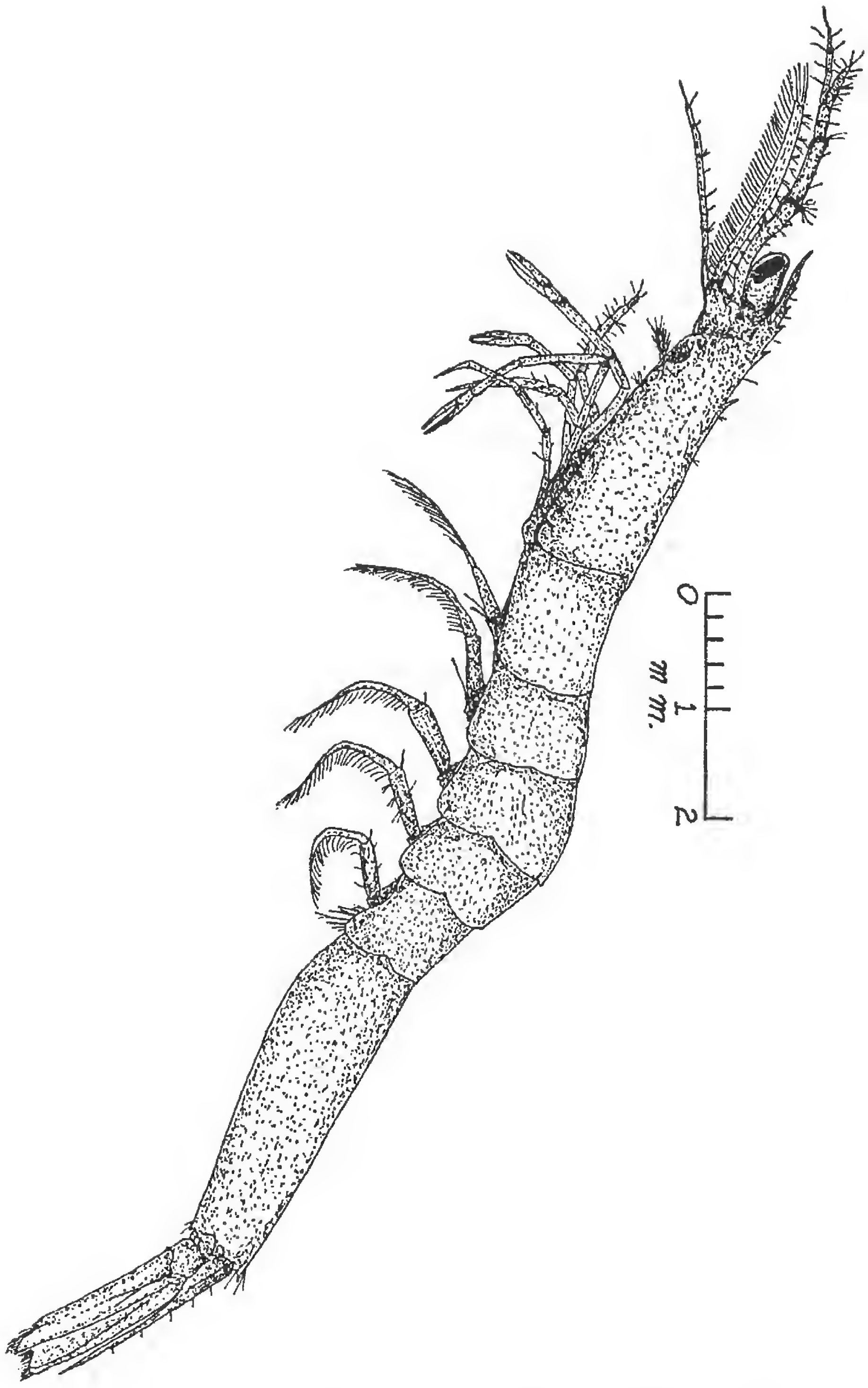


Figure 2. — Brown shrimp postlarva collected 2 March 1964.

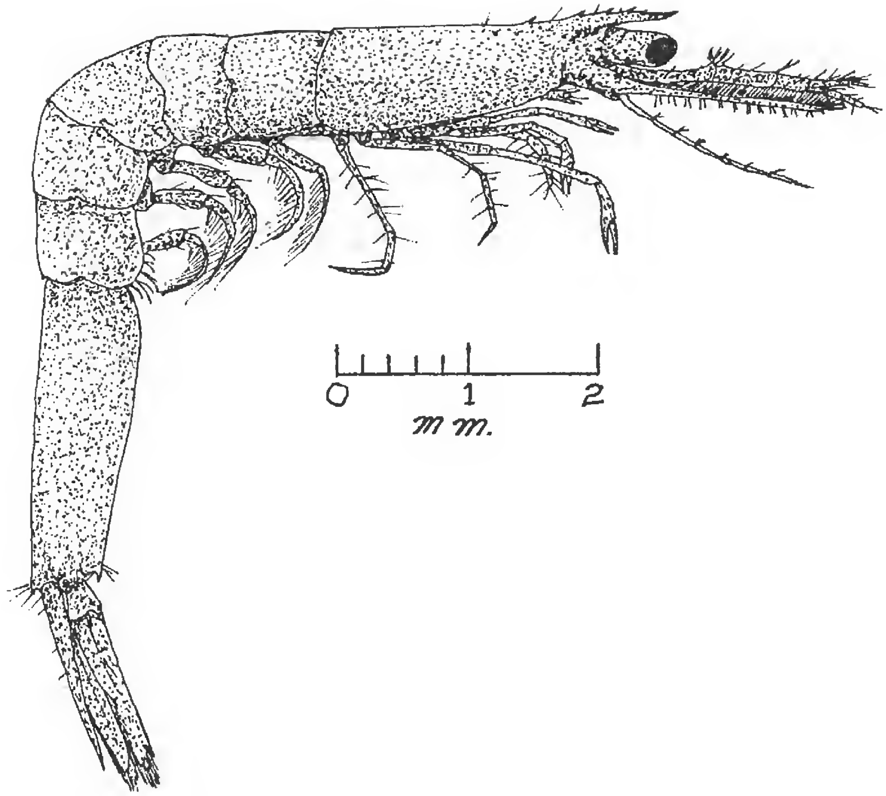


Figure 3. — Brown shrimp postlarva collected 12 August 1964.

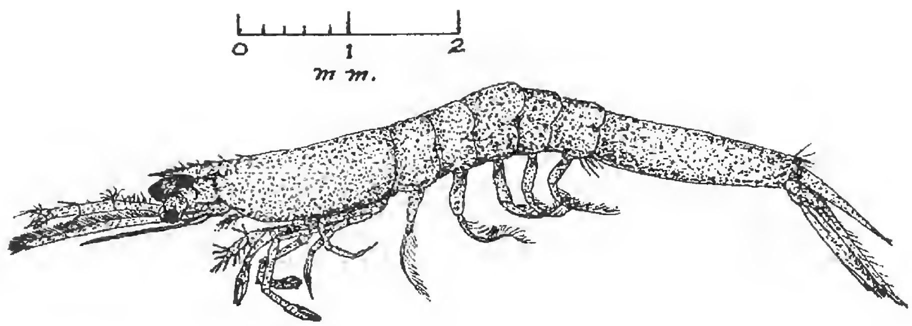


Figure 4. — White shrimp postlarva collected 29 July 1964.

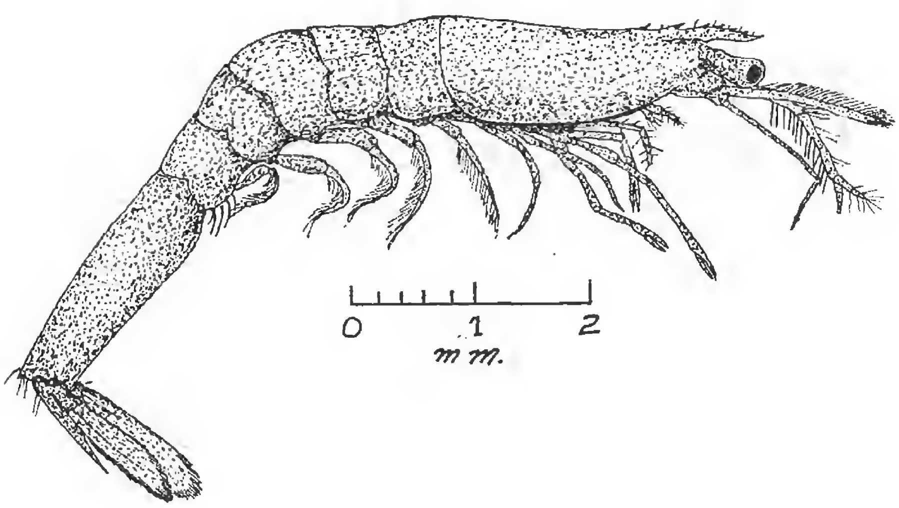


Figure 5. — Pink shrimp postlarva collected 29 July 1964.

culty was encountered at established stations because of soft bottom. This phenomenon was observed in other areas as well as at established stations and evidently was not caused by repeatedly walking over the same path.

The diurnal tides in the Mississippi Sound have a predicted range of a little over 1.5 feet and a mean tide level of .8 - .9 feet. However, the cyclic predictions are subject to drastic modification by wind. Large areas of shallow flats are sometimes uncovered when winds are from the north. Prolonged periods of easterly and southeasterly winds sometimes keep the marshes flooded for long periods. These periods vary from year to year and may, as suggested by Collier and Hedgpeth (1950), influence the success of a given year class of shrimp or other estuarine organisms.

Salinity

The major rivers bringing fresh water into Mississippi Sound are the Pascagoula and the Pearl. Streams with smaller drainage areas enter Biloxi Bay and the Bay of St. Louis. Numerous tidal bayous drain the coastal area. Annual rainfall in the area is usually heavy, averaging about 65 inches. Seasonal and annual variations are sometimes large. Consequently the salinity in the estuary is subject to sudden and drastic changes for short periods with longer term differences that may be considerable.

Table 5 shows monthly average salinity at 16 stations. Barrier island stations have been separated in the table so that the higher salinities along the islands is evident. Both mainland and barrier island stations have been arranged in geographic order from east to west.

In general, salinity was unusually high from the beginning of the project in November, 1962 until January, 1964. Seasonal differences, however, were evident during this period. Beginning in January 1964 salinity decreased throughout the area and remained below levels observed during the same month of the year before. In the two periods of postlarval immigration it is evident (Figure 6 and table 5) that salinity was quite different. The figure illustrates annual differences, differences between barrier island and mainland stations, and fluctuations within months.

Water Temperature

Water temperature in the shallow waters of Mississippi Sound and adjacent waters is subject to large seasonal variations. The lowest temperature we recorded occurred at station 1 in January, 1964, when the thermometer showed 3.4° C. The highest temperature, 36.5° C., occurred at station 21 in June, 1963. Temperatures between 34 and 35° C. were noted at several stations between May and September. Since all temperatures were taken in shallow water near shore, the highs probably represent extremes which occurred in the afternoon on clear, still days. Lows occurred during cold spells when no postlarvae were present and sampling was at a minimum.

Averages (Table 6) changed a little less from month to month and were usually a little lower at barrier island stations. However, minimum and maximum weekly averages usually came from mainland stations. Monthly averages for two years were very similar (Figure 7). They were a little lower in the spring months of 1964. Differences for some weeks in March and April were considerable.

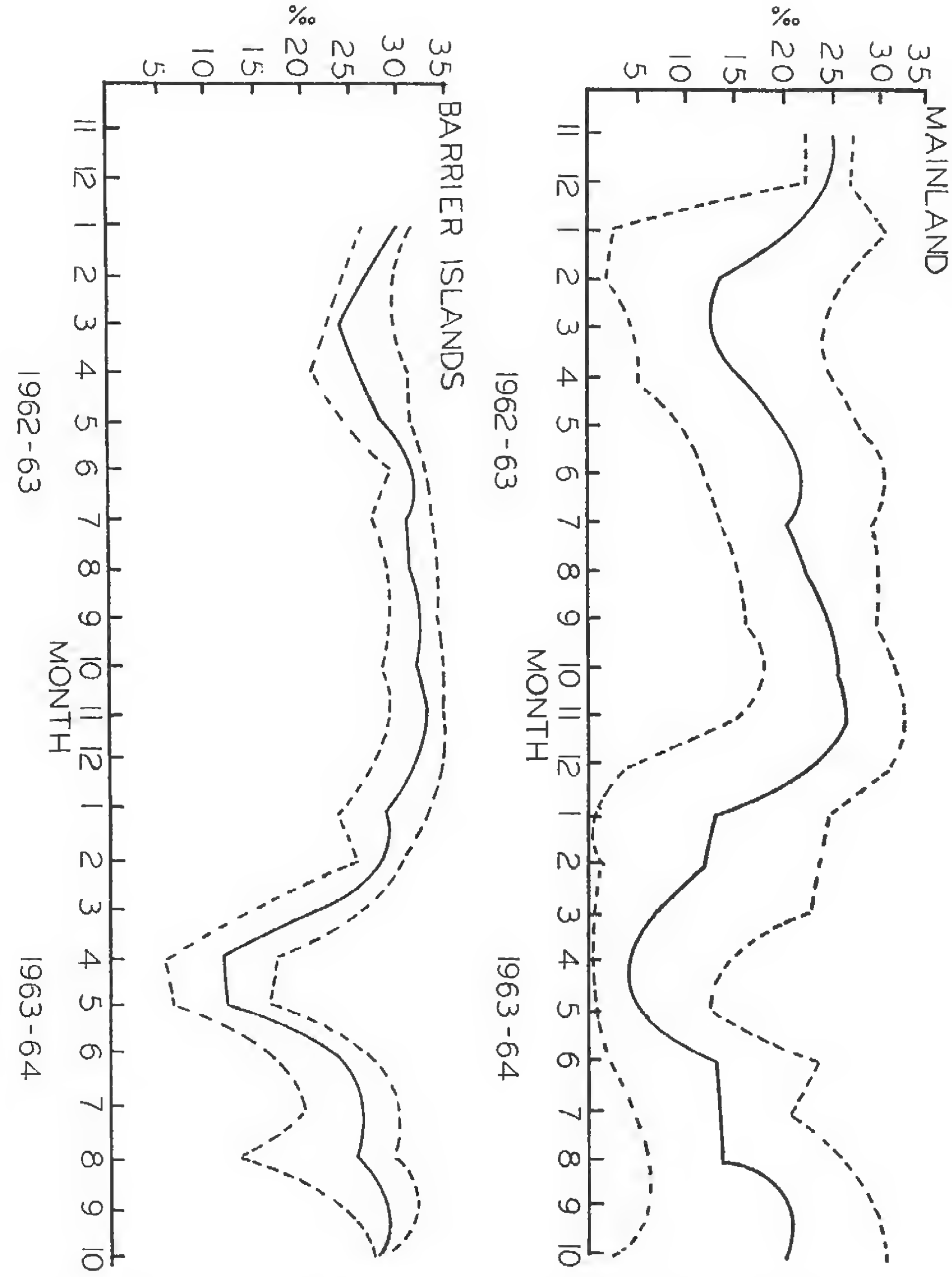


Figure 6. — Average salinity at barrier island and mainland stations with minimum and maximum observations for each month.

Table 5. Monthly average salinity, o/oo, at selected stations. Numbers have been arranged in east-west geographic order.

		Mainland Stations									Barrier Island Stations						
		15	29	11	4	1	23	18	20	19	22	13	8	26	27	25	24
Nov.	1962				26.8	22.7							31.9				
	1963		30.4	28.9	30.1	29.4	28.6	24.1	18.7	21.1	33.1	32.7	32.9	33.5	33.6	33.1	30.3
Dec.	1962			27.1	26.1	24.2											
	1963			27.2	29.8	27.0	26.5	17.8	12.4	15.7	31.2	31.2	31.4	33.5	33.4	33.9	29.0
Jan.	1963	21.1		19.1	22.2	21.8		21.0		16.3		29.6	29.9				
	1964			15.9	19.0	13.7	17.0	13.1	3.3	8.7	31.2	27.1	28.8				
Feb.	1963	4.5		16.3	18.9	13.5	22.0	16.1	7.5	12.8	27.7	26.3	27.5				
	1964		11.2	13.9	21.8	12.2	19.5	12.6	5.9	7.5		28.1	29.0		26.5		
Mar.	1963	11.4		18.3	12.2	11.1	19.8	15.1	7.3	11.6	21.3	25.5	26.4	25.8		24.3	22.7
	1964		11.8	7.0	12.2	9.0	14.1	6.1	2.8	5.0		20.8	22.4				
Apr.	1963	15.2		18.0	20.9	18.6	18.8	13.8	10.2	13.2	26.2	26.1	27.1	26.9	26.2	25.5	23.7
	1964		3.3	6.3	6.7	5.0	6.2	2.6	1.3	2.4	11.3	10.8	10.8	15.5	14.3	11.4	9.1
May	1963	20.8		22.5	24.0	20.1	21.0	17.4	12.3	16.8	27.9	27.1	28.8	28.5	28.9	28.2	26.5
	1964		7.4	6.1	9.3	5.3	5.9	2.4	1.2	2.3	13.3	12.6	14.3	11.0	10.7	9.0	8.3
June	1963	24.0		24.1	25.7	22.6	24.2	22.2	16.9	21.3	30.8	31.2	32.2	31.4	31.6	31.1	30.2
	1964		17.0	20.3	18.5	15.1	14.1	10.8	4.3	8.7	23.6	23.2	23.2	22.8	23.1	23.6	19.0
July	1963	20.5		23.3	22.7	18.4	22.3	22.1	16.1	20.6	31.0	30.5	32.1	30.7	31.2	31.1	29.0
	1964		14.6	14.3	19.0	12.7	16.9	13.4	6.5	11.9	27.1	26.1	26.9	25.8	25.4	25.3	21.3
Aug.	1963	21.4		23.9	26.9	22.0	25.6	21.3	16.3	21.5	31.4	30.8	32.9	32.9	33.0	34.0	30.8
	1964		17.8	17.3	20.7	12.0	19.3	14.0	7.3	13.2	25.5	24.4	26.1	26.2	25.2	26.3	18.0
Sept.	1963	26.1		26.7	27.7	25.4	29.0	25.2	17.4	22.0	32.3	31.4	31.7	32.4	32.4	33.1	31.8
	1964		27.3	24.0	26.4	20.4	24.4	19.6	10.3	15.4	29.1	28.1	28.3	28.3	28.0	26.6	25.5
Oct.	1963		30.7	28.2	29.3	26.4	28.5	23.2	20.4	20.5	32.8	31.6	32.2	32.2	31.9	30.8	29.5
	1964		25.5	24.3	26.9	22.9	25.7	18.1	9.0	15.0	28.5	26.9					

Table 6. Monthly average temperature, °C., at selected stations. Numbers have been arranged in east-west geographic order.

		Mainland Stations									Barrier Island Stations						
		15	29	11	4	1	23	18	20	19	22	13	8	26	27	25	24
Nov.	1962				16.6	18.7							18.5				
	1963		18.0	18.2	19.8	22.1	18.3	18.3	18.7	18.3	18.9	18.2	17.6	19.2	19.3	18.0	18.5
Dec.	1962			14.5	13.5	12.8											
	1963			10.1	13.9	13.7	11.6	13.1	15.0	12.8	10.7	11.2	12.5	14.9	14.8	16.4	17.3
Jan.	1963	16.3		14.7	12.2	12.4		11.4		11.6		11.5	10.8				
	1964			13.9	11.6	9.5	13.8	13.6	12.6	11.9	9.1	9.2	9.8				
Feb.	1963	14.5		17.6	14.0	13.9	14.9	10.8	11.8	10.9	10.8	11.2	10.6				
	1964		12.3	15.3	14.5	15.2	15.8	15.9	12.9	13.8		12.2	13.1		13.8		
Mar.	1963	21.6		21.3	22.0	21.7	18.7	19.4	19.6	18.9	17.1	17.0	16.2	17.0		18.2	18.1
	1964		17.4	18.0	18.4	20.0	18.6	18.4	17.9	18.2		16.3	17.3				
April	1963	25.6		24.4	24.9	24.4	25.6	24.2	24.7	23.7	23.3	22.8	23.3	23.7	24.1	23.1	23.9
	1964		22.9	22.0	22.5	23.9	25.0	24.3	22.7	23.2	24.0	21.9	22.8	23.7	24.6	22.9	26.8
May	1963	30.4		28.2	30.2	27.5	27.1	26.3	27.0	27.3	28.4	26.3	27.3	26.5	28.6	25.7	26.4
	1964		26.7	26.8	28.0	29.6	28.5	28.5	27.7	28.0	27.5	26.5	26.8	27.0	26.0	26.5	27.9
June	1963	29.2		25.9	27.4	29.8	29.5	29.3	29.5	29.6	30.4	29.7		30.7	30.8	30.1	31.6
	1964		31.6	31.5	29.4	30.7	30.2	30.0	29.8	29.3	30.0	29.6	30.4	30.2	32.1	30.3	32.8
July	1963			28.5		29.5	30.3	29.9	31.0	31.0							
	1964		29.9	29.8	29.0	30.6	28.5	28.2	29.0	27.9	29.2	29.3	29.7	30.2	31.0	30.3	33.4
Aug.	1963			27.5		29.7	31.3	31.8	31.2	31.0							
	1964		31.5	31.6	29.9	31.3	30.6	30.4	30.0	30.3	30.1	29.5	29.7	30.5	31.1	30.7	30.8
Sept.	1963	31.7		26.6		27.7	28.5	29.0	28.4	27.9	31.9	29.5	31.0	29.4	29.5	30.3	28.5
	1964		28.6	28.6	28.7	30.6	29.8	29.8	29.2	30.4	29.3	28.4	30.0	30.3	31.1	30.4	31.7
Oct.	1963		22.7	21.8	23.6	24.7	25.5	23.1	23.0	23.6	24.9	24.0	23.3	24.7	23.0	23.0	23.3
	1964		23.4	22.4	22.7	22.2	24.0	23.0	22.7	20.4	23.3	19.9					

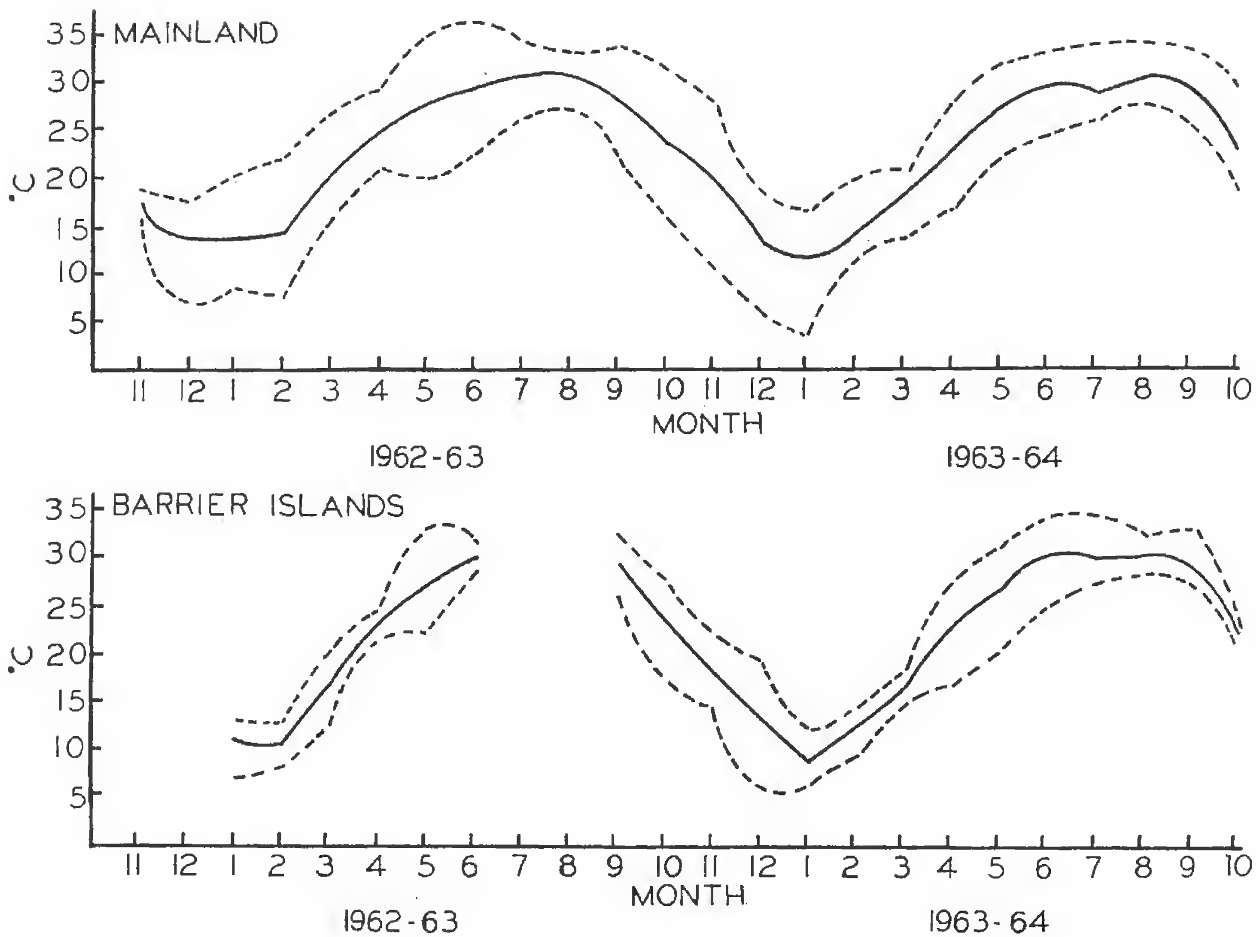


Figure 7.—Average temperature at barrier island and mainland stations with minimum and maximum observations for each month.

Turbidity

Water along the barrier islands is often clear. Inshore stations were usually muddy and especially so when southerly winds had waves moving across shallow area with mud bottoms. High winds or heavy rains cause the turbidity to increase throughout the Sound. Light penetration was reduced occasionally by dark brown organic coloring dissolved in the water coming out of marsh areas.

Organic Debris

As has already been indicated, large quantities of debris were taken in the net on many occasions. Dead grass collected at the swash line and for several feet from the beach occasionally required that the net be lifted before it could be hauled out. At other times large quantities of finely shredded and broken grasses were adrift and on the bottom.

Colonial bryozoans, particularly *Zoobotryon pellucidum* and *Bugula* spp. sometimes drifted into the sampling area in large quantities. At times the net came in almost completely filled with *Zoobotryon.*

In the fall, winter, and spring when the water was cool, algae of various kinds grew at some stations, and the abundance occasionally was great enough to cause trouble in the sample. This was particularly true when additional material had drifted into the sampling area.

Small bunches of sargassum were sometimes encountered. During this two year period there was not an extensive influx of drifting Sargassum like that encountered by Baxter (1962) in the spring and summer of 1962. Larger quantities of *Sargassum* have been observed in Mississippi Sound on several occasions during the past ten years. One of these occurred at the same time Baxter's (*op. cit.*) sampling in Galveston Bay was disrupted in 1962. Attached species growing on the rocks around Ship Island broke loose in rough weather and drifted into the sampling area at some stations.

Fecal pellets collected along the shore in large quantities on some stations.

Associated Animals

Little is known about the interrelationships of the many species of animals occupying the nursery area with penaeid postlarvae and collected in our samples. Time did not permit study of this material but some observations seem pertinent to this problem. The extent to which the abundance of predator and forage organisms affects the success of any brood of penaeid postlarvae is unknown.

Large numbers of other crustaceans were taken in samples with penaeid postlarvae. Palaemonids and mysids occurred in most samples with commercial penaeid postlarvae, often in large numbers. Swarms of the little sergestid, *Acetes,* occurred periodically literally filling the bag of the net. In March, 1963, a large copepod, *Anomalocera ornata,* appeared in tremendous swarms along the Mississippi Sound shore of Horn and Ship Islands. It remained active about a week, filling the net in every sample taken in the area. Afterwards it was seen in windrows on the beaches at the swash line. This was the only time the species was observed in our samples.

Horseshoe crabs, both adults and earlier stages, were collected in

several samples. Blue crabs in various stages of development were often abundant. Hermit crabs were sometimes so abundant that they had to be removed from the sample before preservation. Other invertebrates noticed in casual observations included polychaetes, haustoriids, leeches, flat worms, parasitic isopods and many others. An octopus was caught in one haul at Station 25.

Coelenterates and ctenophores were so abundant at times that they quickly filled the net. Few postlarvae were caught in samples including large quantities of ctenophores. Whether this resulted from failure of the net to fish properly after fouling with the "jelly" or from absence of young shrimp in the area is not known.

Amphioxus appeared in some samples. The larvae and juveniles of many fishes and the small adults of several species were often collected in considerable abundance. Young sciaenids, engraulids, and clupeids were especially noticeable. A few large fish, including stingrays, flounders and sheepshead, were caught but larger specimens usually escaped the net.

THE CATCH OF COMMERCIAL PENAEIDS

A total of 1305 samples was completed. They contained 71,529 postlarvae belonging to the three major commercial species. Table 7 shows the number of samples completed at mainland and barrier island stations. Total numbers and average catches are shown for brown (*Penaeus aztecus*), pink (*P. duorarum*), and white (*P. fluviatilis*) shrimp. Although a small percentage of the annual commercial catch in Mississippi Sound is always pink shrimp, their postlarvae have not been previously reported in the area. *Trachypeneus* postlarvae and young *Xiphopeneus* were also included in the catch. Since they were caught in only a few samples and are not recorded as a part of the area commercial catch they will not be considered here.

Some juveniles of all three major species were taken in the beam net. However, both the size of the net and the sampling area probably limited the catch of juveniles. They were seen escaping over and around the net on some hauls. It should be noted, nevertheless, that brown shrimp juveniles appeared in our catch later in the spring of 1964 than they did in 1963.

DISTRIBUTION

Areal

Monthly average catches of brown shrimp per haul for 16 stations is shown in table 8. Station 29 was established in October 1963 when station 15, across the Pascagoula river, was abandoned because of extensive dredging operations in the Pascagoula ship channel. Sampling at the new station was continued but the catches did not seem to be comparable to that at the old station (15). Few shrimp were caught at station 14 on Round Island and it was finally abandoned. Stations 28, 30, and 31 (Figure 1) were established in the second year of sampling and are not included in this table. Station numbers between 1 and 31 which are not shown in figure 1 were used for stations in various locations. Efforts to sample at these stations were abandoned after a few samples were completed. In most cases, the bottom was too soft to walk on. Tables 9 and 10 give similar data for white and pink shrimp respectively. The 16 remaining stations

have been arranged in east to west order along the mainland and the barrier islands.

In general, postlarvae were more abundant at mainland stations, with the greatest concentration found at Biloxi Bay stations. Variations in east-west distribution was not evident but the largest hauls were made near river mouths.

At barrier island stations more shrimp were taken at stations which included grass beds. These stations, 13, 27, and 24, were located away from the strong currents associated with the ends of Horn and Ship islands. Evidently most of the postlarvae moved through the wide passes without stopping along the island beaches.

Weekly data sheets show irregular variations in the catch at different stations but monthly averages are consistently higher at stations 1, 4, and 11 on the mainland and at stations 13 and 24 on the Islands. Over half of the total catch of postlarvae was taken at these stations.

Temporal

Examination of table 8 shows that the first brown shrimp postlarvae were caught in February in both 1963 and 1964. Weekly data sheets show brown shrimp juveniles about three weeks earlier in 1964 than in 1963. Earlier distribution over the whole area is evident (table 8) in average station catches for 1964.

Immigration continued through the summer and a few brown shrimp postlarvae were found at mainland stations through October. Some specimens are shown in November 1962. The total catch at all stations shows only 17 specimens recorded for November 1963.

No postlarvae were caught at barrier island stations in February 1963

Table 7. Total catch of brown, pink, and white shrimp postlarvae at mainland and barrier island stations with species totals and average catch per haul.

	No. Hauls	No. Brown	No. Pink	No. White	Totals	Average Catch Brown	Average Catch Pink	Average Catch White
1962-63								
Mainland	427	16,332	1,396	8,443	26,171	38.2	3.3	19.8
Barrier Is.	224	2,412	1,960	1,646	6,018	10.8	8.7	7.3
Totals	651	18,744	3,356	10,089	32,189	28.8	5.2	15.5
1963-64								
Mainland	439	20,481	998	8,171	29,650	46.7	2.3	18.6
Barrier Is.	215	5,610	404	3,686	9,700	26.1	1.9	17.1
Totals	654	26,091	1,402	11,857	39,350	39.9	2.1	18.1

Table 8 Average haul of brown shrimp postlarvae at certain stations by months and years. Stations have been arranged in east-west geographic order.

Mon./	MAINLAND STATIONS									BARRIER ISLAND STATIONS						
Year	15	29	11	4	1	23	18	20	19	22	13	8	26	27	25	24
Nov.																
1962				62	2							0				
1963		2	0	0	0	0	0	0	1	0	0	0	0	0	0	2
Dec.																
1962			0	2	0											
1963			0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jan.																
1963	0		0	2	0		0		0		0	0				
1964			0	0	0	0	0	0	0	0	0	0				
Feb.																
1963	0		0	0	0	6	0	0	0	0	0	0				
1964		1	5	29	13	2	3	0	4		4	1		0		
Mar.																
1963	33		78	99	67	1	6	4	25	1	14	2	0		1	3
1964		74	84	153	379	24	110	3	63		14	11				
Apr.																
1963	241		84	262	54	14	4	18	88	0	6	1	0	1	0	15
1964		31	139	270	249	33	58	1	146	0	12	7	3	6	4	57
May																
1963	162		42	353	59	21	49	35	26	6	32	1	5	7	0	26
1964		86	50	125	24	26	6	0	32	2	31	12	5	8	2	122
June																
1963	86		100	387	27	41	24	15	20	4	134	47	1	24	14	100
1964		40	15	170	33	17	4	2	10	4	266	119	5	29	2	69
July																
1963	106		163	268	40	22	13	9	10	4	32	2	1	38	2	58
1964		21	43	227	15	7	5	3	7	6	171	35	2	1	3	166
Aug.																
1963	56		36	122	11	10	1	25	20	2	11	12	2	10	2	28
1964		26	78	420	74	30	1	7	5	9	160	28	3	1	2	78
Sept.																
1963	14		22	36	1	1	8	0	15	10	3	4	4	6	0	10
1964		38	27	266	5	4	5	4	32	0	24	20	0	2	6	24
Oct.																
1963		1	3	5	3	1	0	1	2	0	0	0	0	0	0	0
1964		10	3	119	3	3	1	1	3	0	1					
Totals																
62-63	96	1	54	134	25	14	12	12	22	3	20	6	2	13	2	29
63-64		36	42	152	72	13	18	2	30	3	63	24	2	6	2	66

Table 9. Average haul of white shrimp postlarvae at certain stations by months and years. Stations have been arranged in east-west geographic order. Figures have been rounded off to the nearest whole number.

Mon./	MAINLAND STATIONS									BARRIER ISLAND STATIONS						
Year	15	29	11	4	1	23	18	20	19	22	13	8	26	27	25	24
Nov.																
1962				0	0							0				
1963		0	0	6	1	1	1	0	0	0	0	1	0	0	0	1
Dec.																
1962			0	0	0											
1963			0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jan.																
1963	0		0	0	0		0		0		0	0				
1964			0	0	0	0	0	0	0	0	0	0				
Feb.																
1963	0		0	0	0	0	0	0	0	0	0	0				
1964		0	0	0	0	0	0	0	0	0	0		0			
Mar.																
1963	0		0	0	0	0	0	0	0	0	0	0	0		0	0
1964		0	0	0	0	0	0	0	0		0	0				
Apr.																
1963	0		0	0	0	1	0	0	0	0	0	0	0	0	0	0
1964		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May																
1963	2		2	3	1	10	10	6	4	1	2	0	0	2	0	1
1964		5	8	22	2	0	1	0	0	38	52	9	0	7	0	8
June																
1963	60		14	26	11	30	2	3	15	1	74	6	7	18	23	15
1964		76	116	84	28	22	15	10	13	2	132	19	4	4	5	16
July																
1963	84		285	114	56	154	40	14	23	2	50	2	6	31	0	3
1964		28	47	89	13	4	8	2	13	0	94	9	2	2	8	17
Aug.																
1963	244		49	90	27	49	32	33	47	2	31	44	7	21	0	18
1964		43	72	313	83	49	9	6	15	19	304	34	8	13	2	66
Sept.																
1963	142		30	62	8	18	10	2	20	11	10	30	12	10	2	4
1964		22	12	285	6	5	2	4	33	9	28	38	1	1	6	8
Oct.																
1963		2	1	12	5	2	1	2	9	0	7	2	0	0	0	3
1964		8	4	164	8	6	6	1	5	1	0					
Totals																
62-63	59	2	42	25	11	34	11	7	12	2	16	7	4	12	3	5
63-64		20	23	75	10	7	9	2	7	8	55	10	2	4	3	13

Table 10. Average haul of pink shrimp postlarvae at certain stations by months and years. Stations have been arranged in east-west geographic order. Figures have been rounded off to the nearest whole number.

Mon./	MAINLAND STATIONS									BARRIER ISLAND STATIONS						
Year	15	29	11	4	1	23	18	20	19	22	13	8	26	27	25	24
Nov.																
1962				0	0							0				
1963		0	1	15	2	2	1	1	3	0	5	0	0	0	0	12
Dec.																
1962			0	0	0											
1963			0	4	0	0	0	0	0	0	0	0	0	0	0	4
Jan.																
1963	0		0	0	0		0		0		0	0				
1964			0	0	0	0	0	0	0	0	0	0				
Feb.																
1963	0		0	0	0	0	0	0	0	0	0	0				
1964		0	0	0	0	0	0	0	0		0	0		0		
Mar.																
1963	0		0	0	1	0	0	0	0	0	0	0	0		0	0
1964		0	0	0	0	0	0	0	0		0	0				
Apr.																
1963	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0
1964		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May																
1963	0		0	1	0	0	0	5	0	0	1	0	0	1	0	1
1964		0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
June																
1963	2		8	6	1	1	1	0	0	0	3	4	1	6	0	12
1964		0	0	1	0	0	0	0	0	0	4	2	0	1	1	0
July																
1963	9		1	21	0	1	2	2	1	4	8	2	5	12	4	19
1964		0	6	4	4	0	0	0	0	1	31	1	2	0	0	0
Aug.																
1963	1		2	9	8	6	2	8	0	0	156	8	8	6	10	78
1964		0	0	46	4	0	0	0	0	0	17	1	0	0	0	2
Sept.																
1963	21		5	14	5	7	17	4	49	38	65	34	0	7	4	12
1964		0	0	41	1	1	1	1	4	0	3	12	0	0	0	0
Oct.																
1963		4	4	15	4	9	1	4	4	0	11	6	0	2	3	27
1964		13	1	80	6	7	1	1	5	0	0					
Totals																
62-63	4	4	2	6	2	3	2	3	4	4	24	4	2	5	2	16
63-64		1	1	13	1	1	0	0	1	0	6	1	0	0	0	3

but a few were found at stations 8 and 13 in 1964. They had practically disappeared from offshore island stations by the end of September in both years.

White shrimp were first found in our samples (table 9) in May of both years. The first white shrimp was taken on May 8, in 1963 at an island station but only one specimen was found in the sample. In 1964 white shrimp were first found on May 20 when 200 specimens were collected at eight stations. However, 144 of these were collected at stations 13 and 22 on Horn Island. Immigration continued through the summer until the end of October. A few specimens were collected in November 1963.

Pink shrimp postlarvae (table 10) were found in some samples from May through December. Only a few were recorded before July in either year. Apparently our sampling included only one complete pink shrimp cycle. The fishery in this area takes pink shrimp in the spring and summer (Gulf Coast Shrimp Data 1963 and 1964). It is unlikely that pink shrimp postlarvae taken in our samples could contribute to the commercial catch until they had survived one winter.

Salinity

Brown shrimp postlarvae were caught at salinities ranging from less than 2 o/oo to 34 o/oo. In the 1962-63 period the highest average catch was found in the 20-21.9 o/oo interval when the catch at stations 1, 4, 11 and 13 were arranged in salinity intervals of 2 o/oo. In the second year the highest average occurred in the 18-19.9 o/oo interval. However, in the second year the next highest average occurred in the 4-5.9 o/oo interval while the first year next to highest average was found in the interval 22-23.9 o/oo. Multi-modal curves of abundance skewed in opposite directions in the first and second year. The two highest peaks for white shrimp occurred in the 28-29.9 and the 16-17.9 o/oo intervals in the first year. In the second year they were in the 18-19.9 and 24-25.9 intervals, respectively.

However, in the second year, when salinity generally was lower, a greater percentage of both brown and white shrimp postlarvae were caught at barrier island stations.

Pink shrimp were caught at higher salinities. The two highest averages occurred in 32-33.9 and 18-19.9 o/oo intervals. The curve of distribution was skewed strongly toward the higher salinity.

Temperature

No penaeid postlarvae were taken at stations 1, 4, 11, and 13 when the water temperatures were 12° C. In general, numbers increased until the temperatures exceeded 30-32° C. Average catches were lower at temperatures above this level.

POSTLARVAL INDEX OF ABUNDANCE

Selection of Stations

The feasibility of a continuing program of sampling postlarval commercial shrimps as a means of predicting the ensuing commercial availability depends largely on the reliability and the cost of the program.

Table 11. The catch of brown shrimp postlarvae at stations 1, 4, 11 and 13.

Month	Year	Average Catch by Weeks 1	2	3	4	5	Total Hauls	Month Averages
Nov.	1962		76	32	48		4	47
	1963	0	0	0	0		16	0
Dec.	1962	5	0	0	0		9	1
	1963	0	0	0	0		12	0
Jan.	1963	2	0	0	0	0	17	1
	1964	0	0	0	0	0	15	0
Feb.	1963	0	0	0	0		14	0
	1964	4	5	26	16		16	13
March	1963	16	59	69	114		16	64
	1964	27	186	107	310		16	158
April	1963	57	196	27	126		16	101
	1964	589	279	52	42	13	19	176
May	1963	84	246	41	136	104	20	122
	1964	41	63	106	19		16	57
June	1963	230	139	34	219		15	164
	1964	52	277	108	46		16	121
July	1963	96	155	47	157	137	19	116
	1964	68	5	168	150	92	19	108
Aug.	1963	98	37	27	18		16	45
	1964	105	176	164	359		15	190
Sept.	1963	7	46	4	5		16	15
	1964	43	9	178	162	18	16	80
Oct.	1963	1	7	1	0	4	20	3
	1964	46	2	4	22		11	24

Table 12. The catch of white shrimp postlarvae at stations 1, 4, 11 and 13.

Month	Year	Average Catch by Weeks 1	2	3	4	5	Total Hauls	Month Averages
Nov.	1962		0	0	0		4	0
	1963	1	6	0	0		16	2
Dec.	1962	0	0	0	0		9	0
	1963	0	0	0	0		12	0
Jan.	1963	0	0	0	0	0	17	0
	1964	0	0	0	0	0	15	0
Feb.	1963	0	0	0	0		14	0
	1964	0	0	0	0		16	0
Mar.	1963	0	0	0	0		16	0
	1964	0	0	0	0		16	0
April	1963	0	0	0	0		16	0
	1964	0	0	0	0	0	19	0
May	1963	0	0	1	4	6	20	2
	1964	0	0	32	5		16	21
June	1963	35	25	15	36		15	29
	1964	164	150	37	9		16	90
July	1963	45	311	15	133	132	19	127
	1964	12	26	56	109	80	19	59
Aug.	1963	40	52	53	32		16	49
	1964	109	131	364	196		15	200
Sept.	1963	36	62	8	6		16	28
	1964	48	6	177	128	49	16	83
Oct.	1963	2	10	1	2	18	20	7
	1964	68	8	6	25		11	34

Table 13. The catch of pink shrimp postlarvae at stations 1, 4, 11 and 13.

Month	Year	Average Catch by Weeks 1	2	3	4	5	Total Hauls	Month Averages
Nov.	1962		0	0	0		4	0
	1963	19	2	0	2		16	6
Dec.	1962	0	0	0	0		9	0
	1963	3	1	0	0		12	1
Jan.	1963	0	0	0	0	0	17	0
	1964	0	0	0	0	0	15	0
Feb.	1963	0	0	0	0		14	0
	1964	0	0	0	0		16	0
March	1963	0	0	1	0		16	0
	1964	0	0	0	0		16	0
April	1963	0	0	0	0		16	0
	1964	0	0	0	0	0	19	0
May	1963	0	0	0	1	2	20	1
	1964	0	0	0	1		16	0
June	1963	8	1	5	5		15	4
	1964	4	1	0	0		16	1
July	1963	2	2	15	0	13	19	7
	1964	0	0	8	38	9	19	12
Aug.	1963	6	59	38	72		16	44
	1964	12	4	23	35		15	18
Sept.	1963	58	7	15	9		16	22
	1964	3	0	25	21	8	16	11
Oct.	1963	1	11	5	6	18	20	8
	1964	29	6	6	16		11	17

Several things indicate that one station sampling would not be satisfactory in Mississippi Sound and adjacent waters. Wide variations, both areal and temporal, in the abundance of postlarvae at stations established in this program have been observed. Differences in distribution of postlarvae from one year to the next have been noted as well as the variety of environmental conditions involved.

In order to be useful in a long term program, stations selected for development of abundance indices must be as accessible as possible, must encompass as many variants of the environment as practicable, must be few in number, and must produce representative numbers of postlarvae.

Four stations used in this project apparently satisfy these conditions. Station 1 is located near the laboratory. A soft mud bottom is bordered by a typical marsh. Station 4 is located on a shallow, moderately firm flat with considerable seasonal grass growing on the bottom. Station 11 is bordered by a clean sand beach facing the open sound. Station 13 on Horn Island is much more accessible than station 24 on Cat Island, the other island station that might be considered. Average hauls at these stations have been consistently higher than those made at other island stations. Sampling at all four stations can be completed by a two-man crew in about four hours. These stations have been used to develop the index of postlarval abundance for Mississippi Sound and adjacent waters. The combined catch at stations 1, 4, 11, and 13 is shown in detail in tables 11, 12, and 13.

For Brown Shrimp

Brown shrimp postlarval immigration begins as early as February at these stations (table 11). The commercial catch takes relatively few brown shrimp (figure 9) after September. It is unlikely that postlarvae caught after July would contribute much to the year's commercial catch. Therefore the index for brown shrimp is taken as the average haul for the period of February through July. The index for 1963 is 97.5 and for 1964 it is 107.5. Dividing the second year index by the first we get 110.3%. Consequently the postlarval index would predict that the commercial crop of brown shrimp for 1964 would be 110.3% of the 1963 catch.

For White Shrimp

White shrimp postlarval immigration started in May of both years (table 12). Movement of postlarvae into the nursery area continued until the end of October with a few postlarvae entering the estuary later. The commercial fishery for the new crop of white shrimp begins in August (figure 10). Commercial fishermen continue to take white shrimp throughout the year. Therefore the entire white shrimp postlarval crop may be available to the fishery within the year. Average numbers of white shrimp postlarvae taken in hauls from May through the remainder of the year are used as the index of postlarval abundance for white shrimp. The index for 1963 is 40.04 and 81.81 in 1964. The second year index is 204.3% of the first. Hence the prediction would be for a catch in 1964 that doubles the 1963 catch.

For Pink Shrimp

As previously indicated our sampling probably did not cover two complete cycles of pink shrimp recruitment. Pink shrimp usually make up

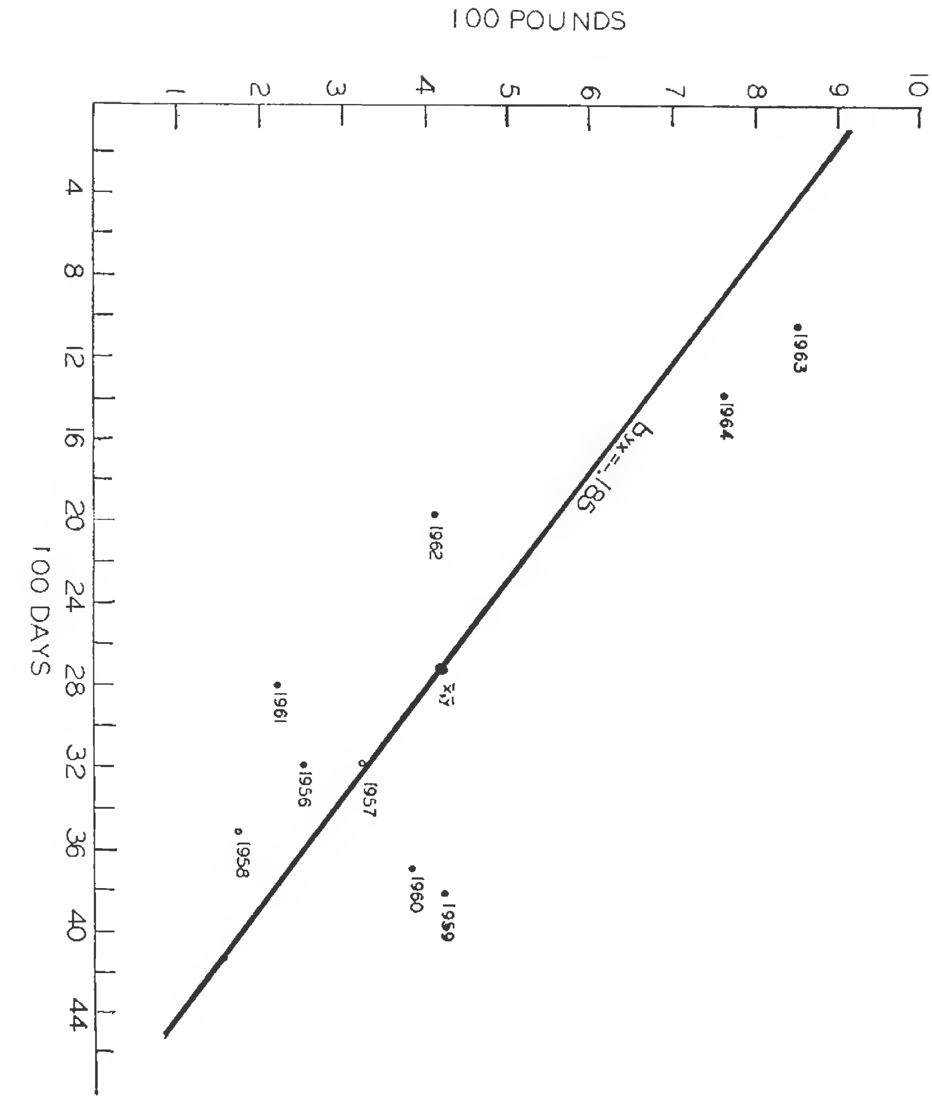


Figure 8. — Relationship of brown shrimp catch per 24 hours fishing to total days fishing in area 011.1, 1956 through 1963.

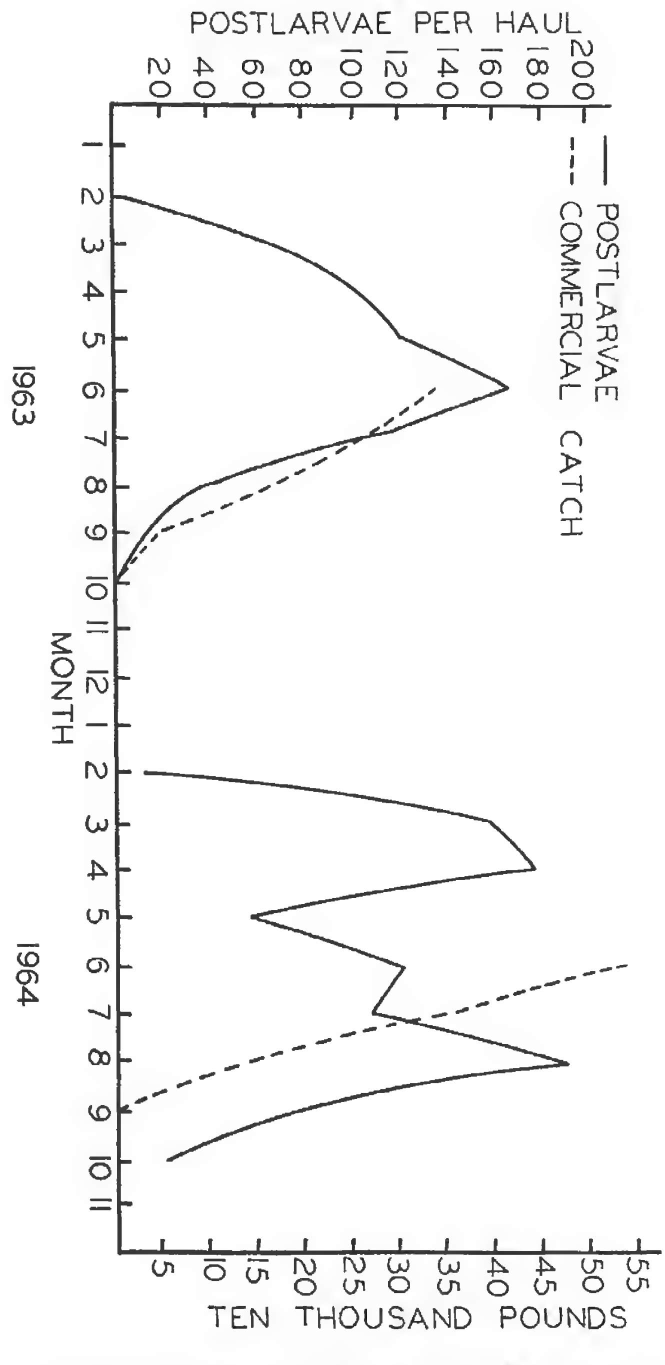


Figure 9. — Monthly average catch of brown shrimp per haul and monthly commercial catch in area 011.1, 1963 and 1964.

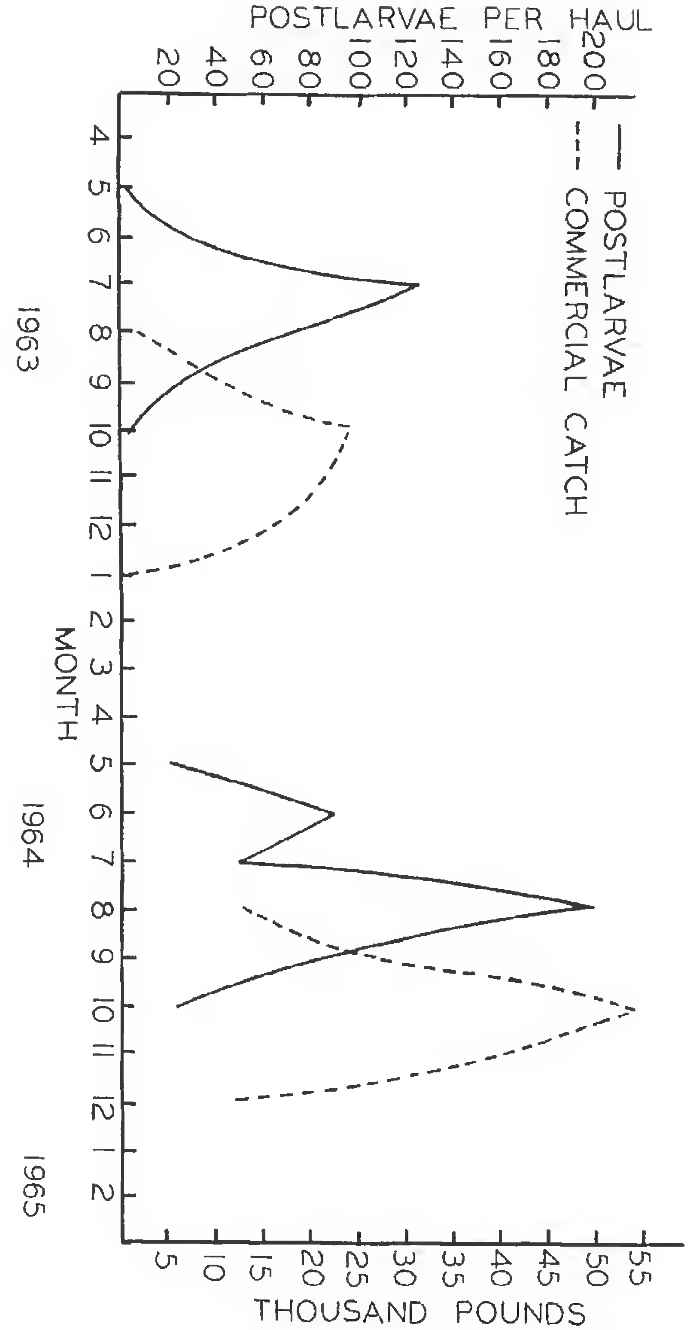


Figure 10. — Monthly average catch of white shrimp per haul and monthly commercial catch in area 011.1, 1963 and 1964.

less than three per cent of the total catch in this area. It is doubtful that our data could be used to produce an index for pink shrimp.

COMMERCIAL FISHERIES INDEX OF ABUNDANCE

Selection of Areas

Since 1956 Gulf Coast Shrimp data, published by the Bureau of Commercial Fisheries, has reported the shrimp catch by species, size, area of capture and depth of water with the number of trips and amount of fishing effort in 24 hour days. Area 011.1 is most closely associated with the area sampled by our stations. It is located in Mississippi Sound, extending from the east end of the Sound to the Gulfport ship channel.

Area 0110 includes offshore Mississippi waters. It extends offshore from the Gulf side of the barrier islands between Mobile Bay and the Chandeleur Islands (see FWS Shrimp Fishing Grid Zones for details). It is known (Lindner and Anderson, 1956) that white shrimp from Mississippi waters enter this area. Abundance indices for both of these areas should be considered.

Derivation of Indices of Abundance

In a heavily fished, restricted area like 011.1 the fishing intensity might affect the catch per unit of effort. The relationship between fishing effort and the catch per 24 hour day of fishing since 1956 is shown in figure 8.

Correlation ($r = -.8018$) between fishing effort and catch per 24 hour days fishing is significant (when $p = .01$, with seven degrees of freedom $r = .7977$). Ninety-five per cent confidence limits of b_{YX} are -.308 to -.062. Since $B = 0$ is not included, the regression of catch per unit of effort is significant.

In 1964 the number of 24 hour days of fishing for brown shrimp in area 011.1 increased from the 1963 effort, 1,082.2 days, to 1,515.7 days. This is 140 per cent of the 1963 effort. Similarly, the effort involved in catching white shrimp in 1964 is 144 per cent of the corresponding 1963 effort. Although the area catch of brown shrimp for 1964 was 84.7 per cent of the 1963 catch per 24 hour day, the total catch was 118.7 per cent. Hence, the total catch in area 011.1 is a better indicator of abundance than the catch per unit of effort. This would, of course, not be true if the intensity did not affect the catch per day. The index for abundance in area 011.1 is determined by the total catch of each species.

In area 0110 the situation is different. There is no evident historical relationship between fishing intensity and catch per day. Fishing intensity does fluctuate and the catch per 24 hour day would evidently be the best indicator of abundance.

For Brown Shrimp

In area 011.1 the catch of brown shrimp in 1964 (1,064,685 pounds) was 118.7 per cent of the 1963 catch (897,039 pounds). The 1964 catch of brown shrimp per 24 hour day in area 0110 was 497.6 pounds. In 1963 this amounted to 459.1 pounds. The 1964 catch was 108.4 per cent of the 1963 catch.

For White Shrimp

Similar calculations for white shrimp (see table 15) show that the 1964 catch in 011.1 was 204.3 per cent of the 1963 catch. In area 0110 the second year production per day was 207.6 per cent of the catch per 24 hour day in the first year.

COMPARISON OF POSTLARVAL INDEX AND COMMERCIAL CATCH

Brown Shrimp

Table 14 shows the relationship between the brown shrimp postlarval index and the ensuing commercial catch in the selected areas. The 1964 commercial catch in area 011.1 was 75, 251 pounds (8.4 per cent) greater than the postlarval index predicted. Figure 9 shows the relationship between the monthly commercial catch and the average catch of postlarvae.

Table 14. Index of postlarval abundance of brown shrimp compared to the commercial catch in adjacent waters.

	1963	1964	1964/1963 per cent
Pl. Index	97.5	107.5	110.3
Catch in Area 011.1	897,039	1,064,685	118.7
Catch per 24 hours Area 0110	459.1	497.6	108.4

Table 15. Index of postlarval abundance of white shrimp compared to the commercial catch in adjacent waters.

	1963	1964	1964/1963 per cent
Pl. index	40.04	81.81	204.3
Catch in Area 011.1	75,570	149,035	197.2
Catch per 24 hours Area 0110	86.6	183.9	207.6

In area 0110, the catch per 24 hour day was 8.3 pounds (1.9 per cent) less than the prediction.

White Shrimp

Table 15 shows the relationship between the white shrimp postlarval index and the ensuing commercial catch in area 011.1 and 0110. In Mississippi Sound, the 1964 catch was 5,534 pounds (7.1 per cent) less than the amount predicted by the postlarval index. In offshore area, the 1964 catch per days fishing was 2.9 (3.3 per cent) pounds greater than that predicted by the postlarval index. Figure 10 shows the relationship between the monthly commercial catch of white shrimp and the monthly average catch of postlarvae in area 011.1.

DISCUSSION

The postlarvae of all three major species can be expected on the nursery grounds at the same time in late summer and fall. Little difficulty with identification was encountered in the spring and early summer. Brown shrimp postlarvae during this period were noticeably larger than whites at the same stage of development. Brown shrimp postlarvae, however, were smaller during the warmer months. Differentiating characters overlapped in many cases. This was particularly true of sizes from about 14mm. total length until the rostral groove was evident on grooved species. Experienced workers recognized subtle differences which they were not always able to clearly describe. Although there were almost certainly some errors in identifications, averages seem to be correct.

Despite the accuracy of prediction made by the indices developed in this short project, reliability has not been established. The indices need further refining. Although most of the shrimp caught in the statistical areas used in this study during a calendar year come from one year class, a fiscal year including the spring months of the year following inshore movement of the postlarvae may reflect the contribution of a year class more accurately.

Evidence of slower development from postlarvae into rapidly growing juveniles in the spring of 1964 and the chance that adverse factors or combinations of factors may affect survival indicate the advisability of monitoring the abundance of juveniles as a check on the success of postlarvae used for an index of abundance.

The occurrence of rather consistently larger numbers of postlarvae at stations 1, 4, 11, and 13, may be partially explained by the movement of Gulf waters through the passes between Horn and Ship Islands (Figure 1). Priddy (1955) adapted data from Phleger (1954) to show that marine *Foraminifera* "mingle with Sound facies and even estuarine facies". All four stations are located near the inner limit of the Gulf facies. However, little is known about the movement of water masses in the Sound and better understanding of these movements would help clarify the picture.

SUMMARY

1. An extensive sampling project in Mississippi Sound and adjacent waters was carried out during the two years between November 1962 and the end of October 1964.

2. Postlarval pink shrimp were reported from this area for the first time.

3. The salinity regime in the years was very different.

4. From a total of 31 stations established, four were selected as being suitable for use in long term studies of postlarval abundance.

5. Indices of abundance developed from the catch of postlarvae at the selected stations predicted the 1964 catch of both white and brown shrimp within ten per cent.

6. Determination of the relative abundance of postlarval penaeid shrimp by season and area in Mississippi Sound and adjacent waters seems to be feasible, but reliability of the indices has not been fully established. Refinement of the indices and several more years experience will be required to refine the predictions.

REFERENCES

Baxter, Kenneth N.

1962. Abundance of postlarval shrimp — One index of future shrimping success. Proceedings of the Gulf and Carribean Fisheries Institute, Fifteenth Annual Session, November, 1962, pp 79-87.

Collier, Albert and Joel W. Hedgpeth

1950. An introduction to the hydrography of tidal water of Texas. Publications of the Institute of Marine Science, University of Texas, vol. 1, no. 2, pp. 125-179.

Lindner, Milton J. and William W. Anderson

1956. Growth, migrations, spawning and size distribution of shrimp *Penaeus setiferus*. United States Fish and Wildlife Service, Fishery Bulletin 106, vol. 56, pp. 553-645.

Phleger, F. B.

1954. Ecology of Foraminifera and Associated Micro-organisms from Mississippi Sound and Environs, Amer. Assoc. Pet. Geol. Bull., Vol. 38, no. 4, pp. 584-647.

Priddy, R. Crisler, M., Sebren, P., Powell, D., and Burford, H.

1955. Sediments of Mississippi Sound and Inshore Water. Mississippi State Geological Survey, University of Mississippi, Bulletin 82, 53 pp.

Renfro, William C.

1962. Small beam net for sampling postlarval shrimp. *In:* Galveston Biological Laboratory — Fishery research for the year ending June 30, 1962. United States Fish and Wildlife Service, Circular 161, pp. 86-87.